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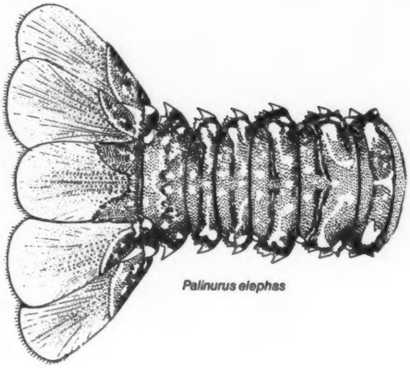

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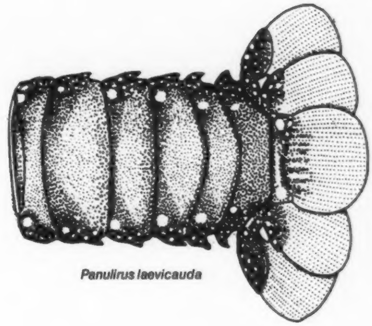

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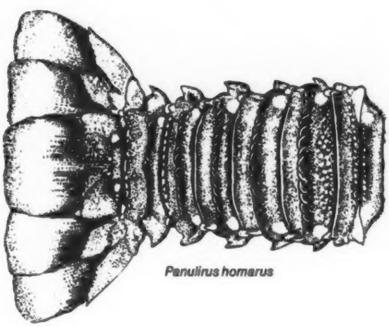

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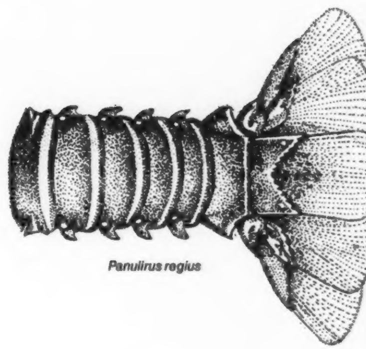

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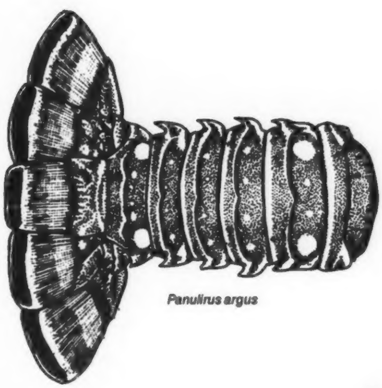

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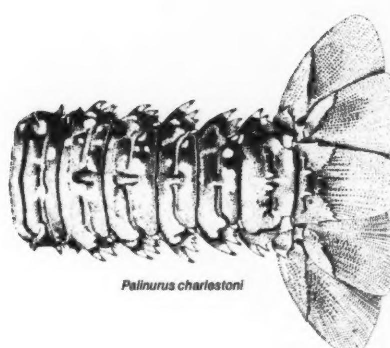
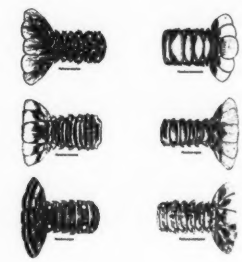


Palinurus charlestoni

Lobster Identification and the U.S. Trade

Marine Fisheries REVIEW



On the cover: Lobster tails from Austin B. Williams' article, page 1.

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Lobsters—Identification, World Distribution, and U.S. Trade

AUSTIN B. WILLIAMS

Introduction

Lobsters are valued throughout the world as prime seafood items wherever they are caught, sold, or consumed. Basically, three kinds are marketed for food, the clawed lobsters (superfamily Nephropoidea), the squat lobsters (family Galatheidae), and the spiny or nonclawed lobsters (superfamily Palinuroidea).

The U.S. market in clawed lobsters is dominated by whole living American lobsters, *Homarus americanus*, caught off the northeastern United States and southeastern Canada, but certain smaller species of clawed lobsters from other parts of the world are also sold, usually frozen or canned. Squat lobsters are sold as frozen tails. Spiny lobsters have no claws and therefore the market for them is confined to the tails which are mainly sold frozen. These come from many parts of the world.

This paper summarizes basic information on the world catch of lobsters, outlines the world distribution of species in the trade, and provides illustrated keys (see box) for identification of the species as they are found in U.S. markets.

The World Catch

The average annual world catch of lobsters for the 7-year period 1975-82 was 401.74 million pounds or roughly one-third of 1 percent of the annual world fishing catch exclusive of marine mammals (Anonymous, 1979a, 1981a, 1983a, 1984; figures converted from metric tons to pounds to conform with U.S. fishery statistics). This total includes clawed lobsters, spiny and flat lobsters, and squat lobsters or langostinos (Tables 1 and 2).

Fisheries for these animals are decidedly concentrated in certain areas of the world because of species distribution, and this can be recognized by noting regional and species catches. The Food and Agriculture Organization of the United Nations (FAO) has divided the world into 27 major fishing areas for the purpose of reporting fishery statistics. Nineteen of these are marine fishing areas, but lobster distribution is restricted to only 14 of them, i.e. the relatively shallow coastal waters of continents and islands, shoal platforms, and certain seamounts (Fig. 1 and 2). Moreover, the world distribution of these animals can also be divided roughly into temperate, subtropical, and tropical temperature zones. From such partitioning, the following facts regarding lobster fisheries emerge.

Clawed lobster fisheries (superfamily Nephropoidea) are concentrated in the temperate North Atlantic region, although there is minor fishing for them in cooler waters at the edge of the continental platform in the Gulf of Mexico, Caribbean Sea (Roe, 1966), western South Atlantic along the coast of Brazil, and Indian Ocean (Venema, 1984). A collateral but less extensive fishery for

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Lobster Keys and Color Figures

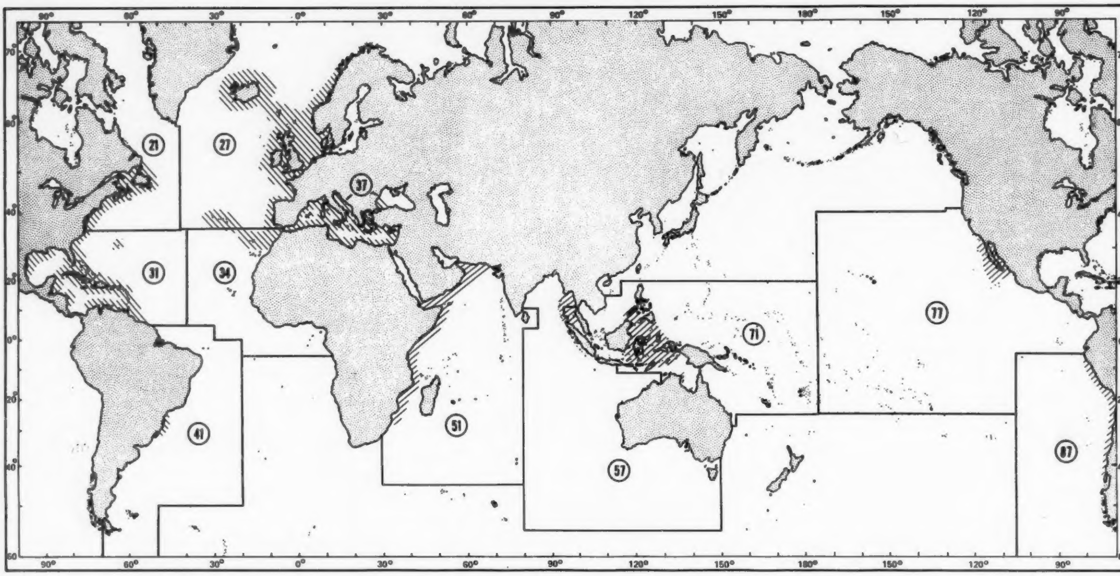


Figure 1.—Contrasting diagonal hatching indicates major fishing areas of world for clawed lobsters (FAO fishing areas 21, 27, 31, 34, 41, 51, 57, and 71 in the Atlantic Ocean, Mediterranean Sea, Indian Ocean, and East Indies) and squat lobsters (FAO fishing areas 77 and 87 in the eastern Pacific). See also Tables 1, 2, and 3.

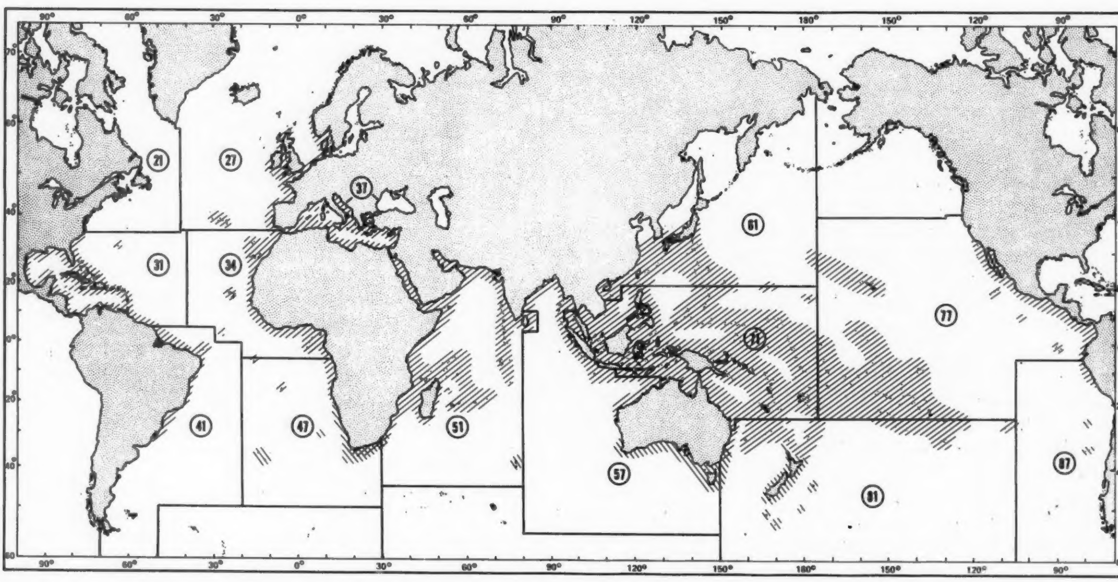


Figure 2.—Major fishing areas of the world for spiny and flat lobsters. Contrasting diagonal hatching indicates distribution of warmwater species (FAO fishing areas 21, 27, 31, 34, 37, 41, 47, 51, 57, 61, 71, 77, and 81) and of coldwater species in the southern hemisphere (FAO fishing areas 47, 51, 57, 81, and 87). See also Tables 1, 2, and 3.

Table 1.—Nominal worldwide landings of lobsters and squat lobsters in millions of pounds by species and major fishing areas for statistical purposes (FAO), 1975-82 (see also Figures 1 and 2). Rounded totals differ slightly from those in Table 2.

Species	Fishing area	1975	1976	1977	1978	1979	1980	1981	1982	$\bar{x}$
Galatheids										
Squat lobsters or langostinos	77, 87	79.06	138.15	95.61	88.24	69.66	27.11	51.70	29.62	72.39
Clawed lobsters										
American lobster, *Homarus americanus*	21	68.75	67.08	71.02	76.70	84.76	81.24	85.36	89.69	78.08
European lobster, *H. gammarus*	27, 37	3.27	4.10	4.25	3.94	3.79	4.40	4.05	4.14	3.99
Southern langoustine, *Metanephrops andamanicus*	51			0.53		0.41	0.63	0.31	0.48	0.30*
Norway lobster, *Nephrops norvegicus*	27, 34, 37	89.81	94.22	96.92	99.33	98.97	96.07	102.42	106.07	97.98
Group totals		161.83	165.40	172.72	179.97	187.93	182.34	192.14	200.38	180.35
Spiny lobsters										
Tropical										
Caribbean spiny lobster, *Panulirus argus*	31, 41	53.91	60.17	59.41	69.30	70.61	65.97	66.41	66.39	64.02
Panulirus spp.										
Western Indian Ocean	51	8.59	13.92	8.37	3.22	3.59	4.87	2.39	1.81	5.85
Australia and East Indies	71	8.61	6.01	8.20	6.78	8.21	6.01	5.39	6.91	7.02
Central and East Pacific	77, 87	4.90	5.14	3.89	3.60	4.54	5.70	7.00	7.39	5.27
Group totals		76.01	85.24	79.87	82.90	86.95	82.55	81.19	82.50	82.15
Subtropical										
Panulirus spp.,										
West Africa (partly tropical)	34	0.07	0.38	0.10	0.97	0.58	0.26	0.43	0.49	0.41
Natal spiny lobster, *Palinurus delagoae*	51	0.12	0.13	0.04	0.16	0.23	0.34	0.32	0.25	0.20
Western red lobster, *Panulirus cygnus*	57	18.21	19.25	20.46	23.68	25.21	23.61	21.92	24.03	22.05
Panulirus spp., Australia										
and East Indies (partly tropical)	57	0.37	2.15	0.61	0.65	0.54	0.29	1.77	1.17	0.94
Green spiny lobster, *Jasus verreauxi*	57, 81	7.84	7.93	7.04	7.09	7.35	7.60	9.87	10.82	8.19
Japanese spiny lobster, *Panulirus japonicus*	61	2.72	2.73	2.78	2.45	2.64	2.64	2.63	2.84	2.68
Group totals		29.36	32.57	31.03	35.00	36.55	34.74	36.94	39.60	34.47
Temperate										
Panulirus spp.										
Northwestern Europe	27	1.11	0.85	0.56	1.06	0.64	0.89	0.61	0.90	0.83
Northwestern Africa	34	1.99	0.65	2.82	2.95	3.59	3.17	1.02	1.16	2.17
Mediterranean Basin	37	2.20	2.13	1.85	2.35	1.91	1.82	2.43	2.30	2.12
Gilchrist's spiny lobster, *Palinurus gilchristi*	47	2.89	2.14	3.66	3.29	2.02	0.43	0.75	0.82	2.00
Cape spiny lobster, *Jasus lalandii*	47	16.40	13.66	15.68	15.87	14.95	14.31	15.25	11.16	14.66
Red spiny lobster, *J. edwardsii*	81	7.31	8.16	7.79	8.27	9.85	10.00	9.98	10.50	8.98
Juan Fernandez spiny lobster, *J. frontalis*	87	0.10	0.11	0.07	0.05	0.09	0.04	0.06	0.11	0.08
Group totals		32.00	27.70	32.43	33.84	33.05	30.66	30.10	26.95	30.84
Flat lobsters										
Slipper lobsters	51, 57, 71, 81	0.30	0.26	0.71	0.63	0.64	0.95	0.98	1.28	0.72
Grand totals		378.56	449.32	412.37	420.58	414.78	358.35	393.05	380.33	400.92

*Average of 5 years

squat lobsters (family Galatheidae) is located in a region under influence of the great temperate current along the western side of South America. The average annual catch of clawed lobsters over the 7-year period 1975-82 (Table 1) was 45 percent of the 401.74 million pound average annual world lobster catch for that period, and the comparable squat lobster catch was 18 percent. Meat yields (tails) of the latter, however, amount to only about 10 percent of their total weight.

Fisheries for lobsters of the superfamily Palinuroidea (i.e. the spiny lobsters, family Palinuridae, and flat lobsters, family Scyllaridae) include about 30 species associated with tropical, subtropical, or temperate climatic regions that are commonly represented in the world catch. There is marked inequality in the contribution of various species to the total catch of this group, and many of the species are not recognized separately in the annual summaries (Tables 1-3). The average annual catch of the group as a whole during the 1975-82 period amounted to 37 percent of the world lobster catch; therefore, though rich in species, spiny lobsters contributed less to world production than did the clawed lobster group.

Probably because of the influence of temperature on the ranges of the commonly exploited spiny and flat lobster species, there are great differences in catches recorded from the different climatic zones (Tables 1-3). Fifty-five percent of the average annual spiny-flat lobster catch during 1975-82 came from the tropical zone, 23 percent from the subtropics, and 21 percent from temperate waters. In the trade, these groups are usually classed as warm water (tropical-subtropical) and cold water (temperate) lobsters. Flat lobsters form almost an afterthought in this discussion, only 0.5 percent of the average annual 1975-82 catch.

From these data it is evident that the temperate waters of the world are more productive of lobsters than are the tropics or their fringes, and this conclusion is reflected in both the specific catches and statistical totals for the major fishing areas. But in all three climatic zones, one or two species stand out above their neighbors in volumes caught: *Homarus americanus* and *Nephrops norvegicus* in the temperate

North Atlantic, *Panulirus argus* in the western tropical Atlantic, *Panulirus cygnus* in the Australasian subtropics, and *Jasus lalandii* in the South African temperate region.

A second level of species landed can also be seen in Tables 1 and 3. These are harder to point out in Table 1 because many of the species caught are not identified precisely enough to be singled out in the FAO statistics, but they are indicated by Morgan (1980) in Table 3: *Panulirus laevicauda* in the American tropical Atlantic and *P. polyphagus* in southern and southeastern Asia; perhaps subtropical *Panulirus inflatus* in the Central American Pacific and *P. japonicus* in Japan; and *Jasus edwardsii* in New Zealand, *P. novaehollandiae* in Australia, as well as somewhat lower amounts of *Palinurus elephas* in Europe, and *P. gilchristi* in South Africa, from what can collectively be regarded as temperate waters.

Table 2.—Nominal worldwide landings of lobsters and squat lobsters in millions of pounds by major fishing areas for statistical purposes (FAO), 1975-82, according to latest published revisions (see also Figures 1 and 2). Rounded totals differ slightly from those in Table 1.

Major fishing area		1975	1976	1977	1978	1979	1980	1981	1982	$\bar{x}$
Atlantic, northwest	21	68.75	66.82	71.02	76.70	84.76	81.24	85.32	89.69	78.04
" northeast	27	87.69	90.14	89.16	95.21	95.70	92.48	104.79	104.79	94.42
" west central	31	46.89	47.65	43.36	52.36	55.09	50.75	47.51	47.01	48.83
" east central	34	3.18	1.34	5.12	4.55	5.13	6.21	2.28	2.30	3.76
Mediterranean and Black Seas	37	8.42	10.89	12.22	10.85	8.65	7.41	6.52	8.06	9.13
Atlantic, southwest	41	10.26	16.16	16.25	16.90	15.67	15.21	18.90	19.38	16.09
" southeast	47	19.29	15.80	19.35	19.17	16.96	14.74	16.02	12.00	16.67
Indian Ocean, western	51	10.32	15.82	8.83	3.19	4.23	5.86	3.03	2.58	6.73
" " eastern	57	26.13	29.08	27.90	31.22	32.95	31.26	33.34	35.78	30.96
Pacific, northwest	61	2.72	2.73	2.78	2.45	2.64	2.64	2.63	2.84	2.68
" west central	71	8.88	6.21	8.81	7.27	8.84	6.87	6.21	8.01	7.64
" east central	77	3.68	4.27	4.07	3.65	9.69	25.20	38.65	22.87	14.01
" southwest	81	7.65	8.47	8.10	8.61	9.81	10.31	10.33	10.88	9.27
" southeast	87	79.16	138.27	95.70	88.29	64.60	7.65	20.11	14.26	63.51
Annual totals		383.02	453.65	412.67	420.42	414.72	357.83	391.04	380.45	401.74

Table 3.—Common species of spiny lobsters, their areas of significant fishery, and approximate catch in millions of pounds, 1976 (adapted from Morgan, 1980).

Species	Areas of significant fishery	Catch
Tropical		
Panulirus argus	Florida, Bahamas, Caribbean, Brazil	50.25
P. echinatus	None	
P. gracilis	Ecuador, Panama	0.60
P. guttatus	None	
P. homarus[1]	East Africa, Indonesia	0.88
P. laevicauda	Brazil	6.61
P. longipes[2]	None	
P. ornatus	New Guinea, East Africa	1.19
P. penicillatus	Reunion, Pacific Islands, Galapagos	0.88
P. polyphagus	Pakistan, India, Southeast Asia	8.16
P. regius	West Africa	0.99
P. versicolor	None	
Subtotal		69.58
Subtropical		
Jasus verreauxi	Eastern Australia, New Zealand	0.28
Palinurus charlestoni	Cape Verde Islands	0.01
P. delagoae	Southeast Africa	0.13
P. mauritanicus	Mauritania, West Africa	0.33
Panulirus cygnus	Western Australia	19.62
P. inflatus	West Mexico, Guatemala	3.31
P. interruptus	California	0.27
P. japonicus	Japan, South China Sea	2.65
P. marginatus	Hawaii	0.02
P. pascuensis	Easter Island	0.01
P. stimpsoni	Hong Kong	0.02
Subtotal		26.65
Temperate		
Jasus edwardsii	New Zealand	8.16
J. frontalis	Juan Fernandez Island	0.11
J. lalandii	Southwest Africa	13.67
J. novaehollandiae	South and southeast Australia	7.72
J. paulensis	St. Paul and New Amsterdam Islands	1.98
J. tristani	Tristan da Cunha	0.01
Palinurus elephas	U.K., France, Spain, Italy	3.31
P. gilchristi	South Africa	2.14
Subtotal		37.10
World total		133.33

[1]Three subspecies.
[2]Two subspecies.

U.S. Trade

Domestic landings of American lobsters averaged 36.6 million pounds annually over the 1975-84 period (Table 4), and annual imports over the same period amounted to 18.4 million pounds of fresh and frozen lobster plus 2.1 million pounds of canned meat (Tables 5 and 6), for an average annual total of 47.1 million pounds on the U.S. market. It is noteworthy that there has been a fairly steady increase in production over this 10-year span and a variable though increasing value in constant dollars, but the fact remains that there is tremendous fishing pressure on the species (Dow, 1980).

Domestic production of spiny lobsters alone averaged 6.2 million pounds annually during 1975-84, both landings and value in constant dollars remaining

Table 4.—Lobster landings in the United States, 1975-84, in millions of pounds, millions of dollars[1], and constant dollars.[2]

Year	American lobster	Million dollars	Constant dollars	Spiny lobster	Million dollars	Constant dollars
1975	29.0	$49.1	$30.46	7.7	$ 9.9	$6.14
1976	31.5	52.0	30.50	5.6	9.3	5.45
1977	31.8	57.9	31.90	6.7	11.2	6.17
1978	34.4	64.6	33.06	4.6	9.7	4.96
1979	37.1	72.3	33.26	6.3	12.8	5.89
1980	37.0	75.2	30.47	6.9	14.8	6.00
1981	37.5	86.5	31.75	6.6	19.4	7.12
1982	39.4	90.9	31.44	6.4	16.1	5.57
1983	44.2	106.8	35.79	5.2	13.7	4.59
1984	44.0	114.3	36.74	6.3	17.3	5.56
$\bar{x}$	36.6		32.54	6.2		5.75

[1]1975-77 from "Fisheries Statistics of the U.S.," Statistical Digest; 1978-84 from "Fisheries of the United States," Curr. Fish. Stat., U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Wash., D.C.
[2]Constant dollars based on 1967 = 100, from "Basic Economic Statistics," Bur. Econ. Stat., Inc., Wash., D.C., 39(4)April 1985.

fairly stable, but that production was dwarfed by average annual imports of 41.5 million pounds of fresh and frozen lobster and a relatively small amount of canned meat, 0.2 million pounds over the same period (Tables 4-6). This impressive annual total of 47.9 million pounds on the U.S. market represents about one-third of the average annual world production of these lobsters (148.18 million pounds) during 1975-82 (Table 1).

Contrast this level of activity with that reported by Chace and Dumont (1949) for the domestic spiny lobster fishery as world fishery momentum began to build after World War II. Annual domestic production then was about 1.0 million pounds. The chief sources for imports were Cuba, the Bahamas, Mexico, South Africa, and later Australia and New Zealand. The United States imported 5.6 million pounds in 1941, 3.3 million pounds in 1945, but 7.8 million pounds in 1948. Domestic production today is more than 6 times that in 1948, and imports are greatly augmented (Tables 4 and 5).

Some Differences Between Lobsters and Shrimps

How can one be sure that a "lobster tail" in a market is that of a true lobster of marine origin and not that of a shrimp, prawn, freshwater crayfish, or crawfish?

Common names used for lobsters in commerce can be misleading. Animals other than lobsters are sometimes given combinations of the name "lobster," such as "lobster shrimp," etc. Conversely, some lobsters bear the names "crawfish" or "crayfish." The differences are sometimes subtle, but the following contrasts may be helpful in making the distinctions.

Lobsters and crayfishes have tail fans in which the middle member (telson) is flattened, bladelike, broad, and sweepingly curved on its terminal edge (Fig. 3). Shrimps, prawns, "lobster shrimps," etc., have tail fans in which this member is drawn to an acute or relatively narrow point. Lobsters have tails (abdomens) that are more or less flattened from top to bottom (wider than deep, i.e. dorsoventrally depressed) whereas shrimps, prawns, and "lobster shrimps" have tails (abdomens) that are narrowed from side to side (deeper than wide, i.e. laterally compressed).

Spiny lobsters and their relatives the flat lobsters have tail fans in which hind parts of the flattened branches are pliable and translucent whereas both clawed lobsters and freshwater crayfishes bear tail fans in which the flattened branches are firm and opaque throughout their length. The clawed lobsters and freshwater crayfishes are not at all easy to distinguish on the basis of tails alone, but as a rule the large-clawed American lobster and much smaller freshwater crayfishes are marketed whole and therefore can be distinguished by size alone. Smaller species of clawed lobsters can be distinguished by the blunt ridges on tails alone.

Squat lobsters or langostinos have tail fans in which the hind edge of the broad middle member is deeply notched in the midline (Fig. 3f). The edge is thus bilobed. Tails of these species are always small.

The following keys are offered as an aid in identifying the tails of lobsters of marine origin in U.S. trade. Species determination is normally based on the entire animal and therefore the difficulties experienced in identifying lobsters from sometimes obscure or variable characters of the tails alone does not necessarily bring validity of the species into question. For those unfamiliar with taxonomic keys of this kind, an explanation of their structure and use is in order.

Each key is composed of numbered and lettered couplets of more or less contradictory statements. To identify a particular lobster tail, one begins with the first couplet and selects the statement (part a or b) which best describes the specimen at hand. From that statement, a guide number at its end leads to the indicated next numbered couplet, etc., until the identity (family, genus, or species name) is finally reached. The couplets usually lead from very great contrasts to less obvious ones; therefore the numbered sequences should be helpful until familiarity is established. The numbers in parentheses indicate the previous couplet used in each case, so that if it is obvious that a wrong choice has been made at some point, steps can be retraced to the questionable couplet without starting at the beginning once more. To make the keys as simple as possible, each named major grouping is

Table 5.—United States imports of fresh and frozen lobster (American includes fresh cooked meat) 1975-84 in millions of pounds, millions of dollars[1], and constant dollars.[2] Squat lobsters included with American lobsters.

Year	American lobster	Million dollars	Constant dollars	Spiny lobster	Million dollars	Constant dollars
1975	15.7	$31.5	$19.54	42.3	$157.1	$ 97.46
1976	15.9	36.2	21.23	48.5	204.5	119.94
1977	15.0	33.9	18.68	45.0	216.4	119.23
1978	13.2	33.8	17.30	43.0	222.5	113.87
1979	16.5	33.1	17.99	44.4	259.4	119.32
1980	14.4	40.5	16.41	36.6	230.2	93.27
1981	17.9	53.1	19.49	38.0	255.7	93.87
1982	19.1	56.4	19.51	35.4	259.2	89.66
1983	25.4	88.0	29.49	38.4	276.0	92.49
1984	30.4	112.9	36.29	43.0	322.7	103.73
$\bar{x}$	18.4		21.59	41.5		104.28

[1]1975-77 from "Fisheries Statistics of the U.S.," Statistical Digest; 1978-84 from "Fisheries of the United States," Curr. Fish. Stat., U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Wash., D.C.
[2]Constant dollars based on 1967 = 100, from "Basic Economic Statistics," Bur. Econ. Stat., Inc., Wash., D.C., 39(4)April 1985.

Table 6.—United States imports of canned lobster meat (American includes fresh cooked meat) 1975-84 in millions of pounds, millions of dollars[1], and constant dollars.[2] Squat lobsters included with American lobsters.

Year	American lobster	Million dollars	Constant dollars	Spiny lobster	Million dollars	Constant dollars
1975	2.0	$10.5	$6.51	0.11	$0.43	$0.27
1976	2.1	10.9	6.39	0.72	3.0	1.76
1977	2.5	14.2	7.82	0.34	1.4	0.77
1978	2.3	15.2	7.78	0.13	0.46	0.24
1979	1.8	10.9	5.01	0.14	0.74	0.34
1980	2.1	12.5	5.06	0.09	0.31	0.13
1981	2.9	19.7	7.23	0.22	0.77	0.28
1982	3.3	25.8	8.92	0.05	0.23	0.08
1983	1.1	8.0	2.68	0.13	0.63	0.21
1984	0.4	2.0	0.64	0.02	0.10	0.03
$\bar{x}$	2.1		5.80	0.20		0.41

[1]1975-77 from "Fisheries Statistics of the U.S.," Statistical Digest; 1978-84 from "Fisheries of the United States," Curr. Fish. Stat., U.S. Dep. Commer., NOAA, Natl. Mar. Fish. Serv., Wash., D.C.
[2]Constant dollars based on 1967 = 100, from "Basic Economic Statistics," Bur. Econ. Stat., Inc., Wash., D.C., 39(4)April 1985.

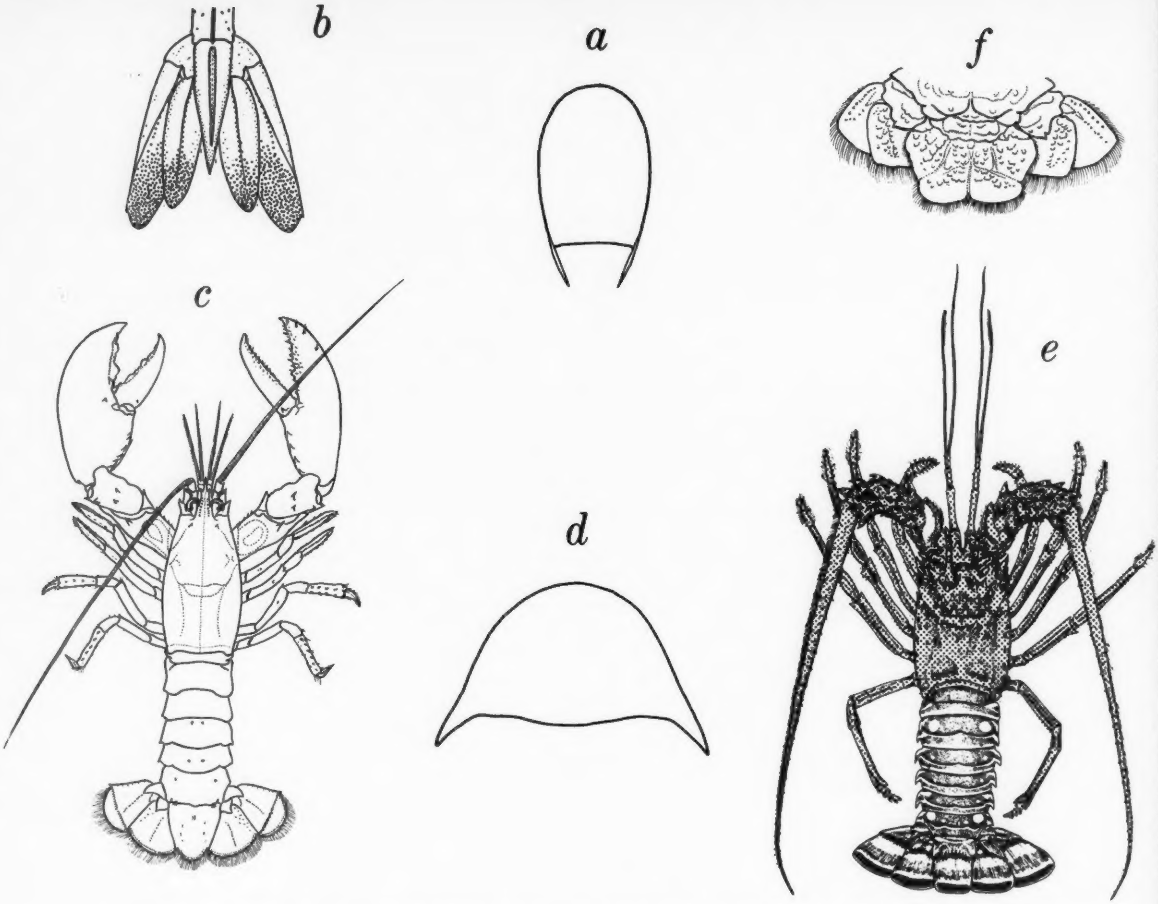


Figure 3.—Some diagnostic features of shrimps and lobsters in U.S. trade: *a*, Cross section outline of shrimp tail showing more or less narrowed (compressed) shape; *b*, tail fan of shrimp; *c*, American lobster, upper surface (adapted from Herrick, 1911); *d*, cross section outline of lobster tail showing more or less flattened (depressed) shape; *e*, spiny lobster, upper surface showing tail in solid tones and remainder of body screened (adapted from Manning, 1978); *f*, tail fan of squat lobster.

treated separately as a subset. In that way the keys form a nested series proceeding from generalities (families and genera) to particulars (species). Family and generic names are given in center headings for speedy reference. Diagrams and color plates are included as supplements to the keys.

Keys for Identification of Lobster Tails (Abdomens) in U.S. Trade

The keys are mostly based on upper surface, side plates, tail fan, and color. Common names, geographic ranges, and depth ranges of species are given in summary form. Common names often vary with language and locality. The names given are those employed in the references section, and the listing is not exhaustive. Symbols entered after species names denote economic importance as follows:

- * Commonly of economic importance.
- † Minor or probable economic importance.
- ‡ No known economic importance but included for completeness.

Lobster or Shrimp Tail?

1a Middle member (telson) of tail fan flattened, bladelike, broad, and sweepingly curved on hind margin (but notched in middle in one group)...Lobster; go to Keys for Identification of Lobster Tails in U.S. Trade, page 7.

1b Middle member (telson) of tail fan more or less triangular, not broad and sweepingly curved on hind margin but drawn to an acute or relatively narrow point...Shrimp; of no further concern in this paper.

Key to Families of Lobsters

1a Middle broad blade of tail fan with median notch in hind margin, forming rounded lobe to either side of midline .... squat lobsters, Galatheidae

1b Middle broad blade of tail fan without median notch in hind margin, its edge gently curved or evenly rounded 2

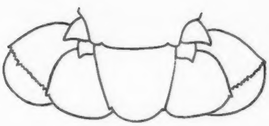


Figure 4.—Tail fan of clawed lobster (from Williams, 1974).

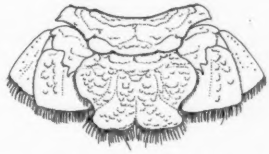


Figure 5.—Tail fan of squat lobster, Galatheidae.

Figure 6.—Tail fan of spiny or flat lobster.

2a (*1*) Flattened branches of tail fan hard and opaque throughout length (Fig. 4)....clawed lobsters, Nephropidae

2b (*1*) Flattened branches of tail fan leathery or somewhat pliable and translucent in hind part, firm and opaque in forepart of length; spiny and flat or shovel-nosed lobsters 3

3a (*2*) Side plates (pleura) of segments 1-6 each ending in single downward projecting strong point tending to be swept obliquely backward; or rarely ending in 2 or 3 widely divergent short spines .... spiny lobsters, Palinuridae

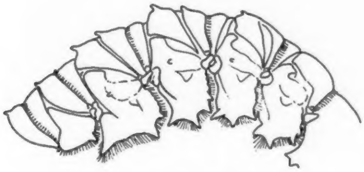


Figure 7a.—Side plates of the spiny lobster *Linuparus trigonus*.

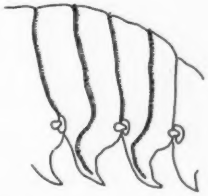


Figure 7b.—Side plates of the spiny lobster *Panulirus longipes* (from Holthuis, 1984).

3b (*2*) Side plates (pleura) of segments 2-6 with downward projecting irregular lobular edges, often bearing granules, tubercles or knobs, or noticeably flattened, with side plates projecting laterally .... flat or shovel-nosed lobsters, Scyllaridae

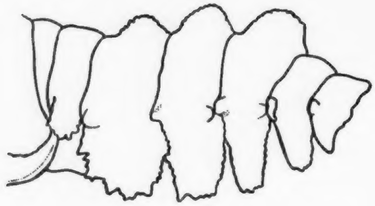


Figure 8a.—Side plates of the flat lobster *Scyllarides haanii* (from Holthuis, 1984).

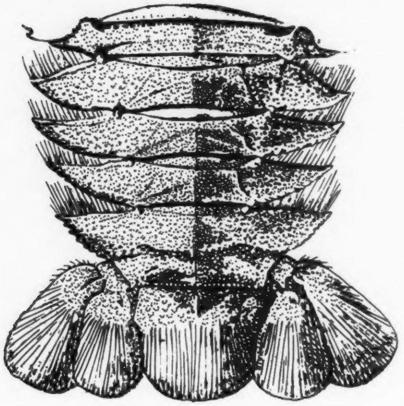


Figure 8b.—Side plates of the flat lobster *Ibacus novemdentatus* (from Holthuis, 1984).

Key to Tails of Clawed Lobsters, Nephropidae

1a Segments smooth, without grooves; no ridges separating arched back plates (terga) from projecting side plates (pleura); robust. Dark bluish green to brownish olive mottled with very dark greenish black spots, often almost black; side plates with reddish tips, orange to whitish below. American lobster. Northwestern Atlantic, Labrador to Cape Hatteras and rarely beyond, low tide mark - 180 m . . . *Homarus americanus* (H. Milne Edwards)*
Also European lobster. Northeastern Atlantic, Lofoten Is., Norway, to Azores and Morocco, Mediterranean and Black seas, low tide mark - 60 m . . . . *H. gammarus* (Linnaeus)*
(These two species are impossible to distinguish on basis of tails alone.)

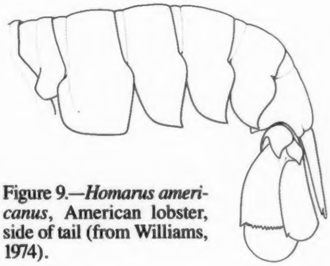


Figure 9.—*Homarus americanus*, American lobster, side of tail (from Williams, 1974).

1b Segments smooth or grooved, but blunt ridge separating arched back plates (terga) from projecting side plates (pleura) 2

2a (*1*) Arched back plates with broad, shallow, hairy grooves interrupted at median line and extending to strongly developed side plates 3

2b Arched back plates not bearing transverse, shallow, hairy grooves 4

3a (*2*) Segment 6 spineless. Pinkish with dark orange-red spots. Norway lobster or scampi. Iceland and western Norway to Morocco, western and central Mediterranean Sea, including Adriatic Sea, 20-824 m, usually 100-300 m . . . . *Nephrops norvegicus* (Linnaeus)*

Figure 10.—*Nephrops norvegicus*, Norway lobster, upper surface of tail (adapted from Holthuis, 1950).

3b Segment 6 with small sharp median spine on hind margin and similar spine to either side of it at rear extremity of side plates; ridge separating arched back plates from side plates ending on each side of segment 6 in small spine. Pinkish or reddish, eggs blue. Indian Ocean off South Africa and Mozambique; Andaman Sea and East Indies, 102-503 m. . . . . *Metanephrops andamanicus* Wood Mason†

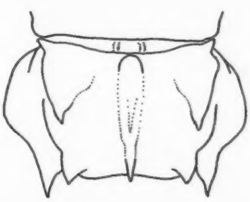


Figure 11.—*Metanephrops andamanicus*, upper surface of segment 6.

4a (2) Low ridge along median line of arched back plates; side plates on segment 2 triangular, tip slender and pointed downward. Variable pink or red, posterior margin of back plates whitish, whitish band on side plates . . . . *Nephropsis*‡
(Florida lobsterette, New Jersey to French Guiana, including Gulf of Mexico and Caribbean Sea, 130-830 m, usually 300-500 m, *Nephropsis aculeata* Smith. (Other rare species could be confused with this species: i.e., *N. rosea* Bate; back plates pale pink, side plates reddish or darker pink; Bermuda, Bahamas, Gulf of Mexico, and Caribbean Sea to French Guiana, 421-1,262 m, usually 550-750 m; or *N. neglecta* Holthuis; red or orange-red; Straits of Florida and Dry Tortugas through Caribbean Sea to Guianas, 655-1,270 m, usually 800+ m).

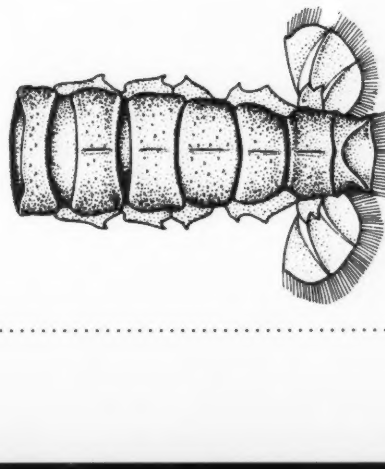


Figure 12.—*Nephropsis aculeata*, Florida lobsterette, upper surface of tail (adapted from Manning, 1978).

4b Arched back plates lacking median ridge 5

5a (*4*) Ridge separating arched back plates from side plates lacking spines or spinules. Pale orange to brownish pink with posterior whitish band on back plates, plates wider in young than adults, side plates white or with brownish orange center. Caribbean lobsterette. Bahamas and south Florida through Gulf of Mexico and Caribbean Sea to French Guiana, 229-703 m, usually 250-600 m . . . . *Metanephrops binghami* (Boone)†

5b Ridge separating arched back plates from side plates bearing 1 or more tiny spines or spinules. Pinkish to orange. Red lobsterette, lagostim, langostinha. East coast of South America roughly between 23° and 30° S (Brazil, from State of Rio de Janeiro to Santa Catarina) . . . . *Metanephrops rubellus* (Moreira)†

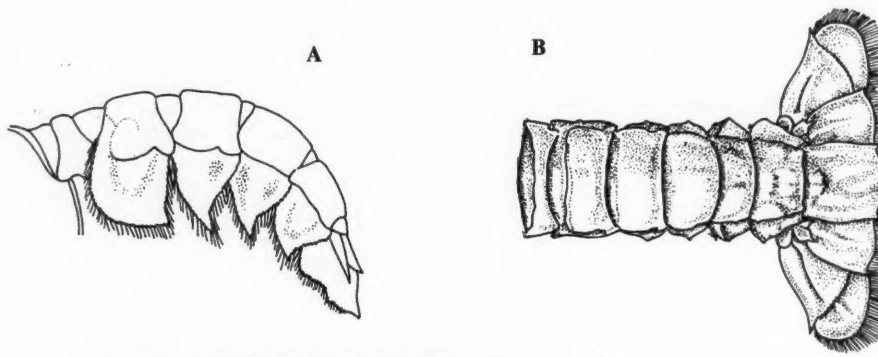


Figure 13.—*Metanephrops binghami*, Caribbean lobsterette: A, Side of tail; B, upper surface of tail (from Manning, 1978).

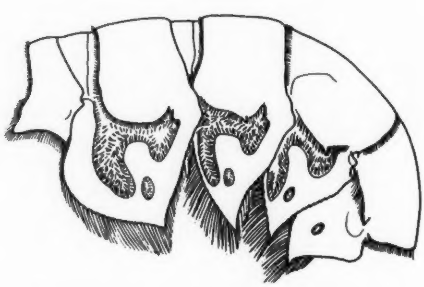


Figure 14.—*Metanephrops rubellus*, side of tail.

Key to Genera of Spiny Lobsters, Palinuridae

1a Segments 2-5 bearing 4-sided design on arched back plates 2

1b Segments 2-5 with arched back plates smooth to variously ornamented, but never bearing 4-sided design 3

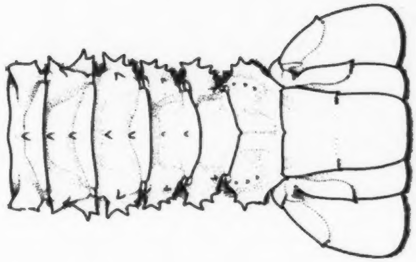


Figure 15.—*Linuparus*, upper surface of tail (from Holthuis, 1984).

Figure 16.—*Panulirus*, upper surface of tail (from Manning, 1978).

2a (*1*) Segments 4-6 with side plates (pleura) bearing more than 2 marginal points (sometimes blunt) . . . . *Linuparus*

2b Segments 4-6 with side plates (pleura) bearing only 2 slender spines (shorter in males than in females and decidedly unequal on 6) . . . . *Puerulus*

Figure 17.—*Linuparus*, side of tail.

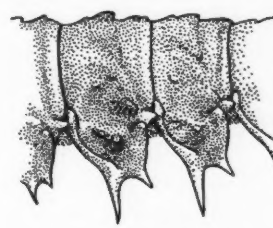


Figure 18.—*Puerulus*, side of tail (from Ramadan, 1938).

3a (*1*) Central blade of tail fan with broad hardened basal plate and series of smaller scales or plates along sides behind it, first one long, slender, and undivided, followed by series of diminishing scales (all may be spine-tipped) . . . . *Jasus*

3b Central blade of tail fan with broad hardened basal plate but usually smooth sides behind it; in one or two species with series of diminishing scales along sides but these never spine tipped and never with first one long, slender, and undivided 4

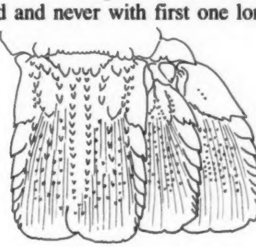


Figure 19.—*Jasus*, upper surface of tail fan.

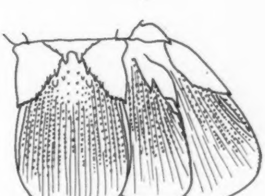


Figure 20.—*Panulirus*, upper surface of tail fan.

4a (*3*) Segment 6 with roughened, subspinose patch of sharp tubercles on upper surface; transverse grooves on arched back plates interrupted in middle, deeply etched or reduced to shallow depression, continuous on segments 2-5 with hind groove of side plate; latter groove irregularly U-shaped, hooking forward and upward; various colors given below .... *Palinurus*

4b Segment 6 smooth to somewhat uneven but not bearing subspinose patch of sharp tubercles on upper surface; transverse grooves on arched back plates, if present, continuous or not continuous on segments 2-5 with foregroove of side plate; various colors given below .... *Panulirus*

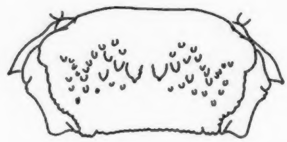


Figure 21.—*Palinurus*, upper surface of segment 6.

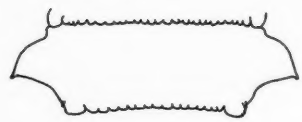


Figure 22.—*Panulirus*, upper surface of segment 6.

Key to Species of *Jasus* (Adapted from George and Kensler, 1970)

1a Arched back plates of segments smooth, without scale-like (squamiform) sculpture. Green, larger adults yellowish brown. Packhorse, green, eastern, common or smooth-tailed spiny lobster. New Zealand (mainly in warmer waters off North Island), New South Wales, and adjacent coast of southeastern Australia .... *J. verreauxi* (H. Milne Edwards)*

1b Arched back plates of segments with obvious scale-like (squamiform) sculpture 2

2a (*1*) Squamiform sculpture covering more than 45 percent of arched back plate surface along midline 3

2b Squamiform sculpture covering less than 45 percent of arched back plate surface along midline 5

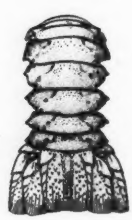


Figure 23.—*Jasus verreauxi*, packhorse, green, or eastern lobster, upper surface of tail (from Kensler, 1967).

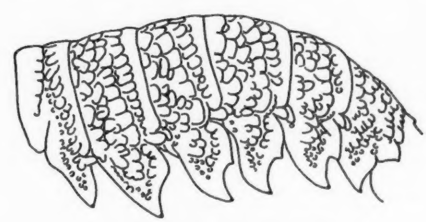


Figure 24.—*Jasus lalandei*, Cape spiny lobster, oblique view, side and upper surface of tail (adapted from George and Kensler, 1970).

3a (*2*) Foremargin of transverse groove on segment 1 sculptured (may be lightly so). Cape spiny lobster. South Africa, (1 reported occurrence off Portugal), intertidal to 90 m. .... *J. lalandii* (H. Milne Edwards)* (Color Fig. 78 a-b.)

3b Foremargin of transverse groove on segment 1 without sculpture 4

4a (*3*) Sculpture covering almost entire upper surface of segments 2-6; squames (scales) numerous and in 4-5 transverse rows (only extreme forward part of segments smooth on each segment). Southern spiny lobster. Tasmania, and southern Australia from Sydney to Freemantle .... *J. novaehollandiae* Holthuis* (Color Fig. 78 c.)

4b Sculpture not covering entire upper surface of segments 2-6; squames (scales) fewer, larger, and in 2-3 rows only on each segment. Red spiny lobster. North and south islands of New Zealand, and Chatham, Bounty, Antipodes and Aukland Islands to east and south... *J. edwardsii* (Hutton)* (Color Fig. 78 d-e.)

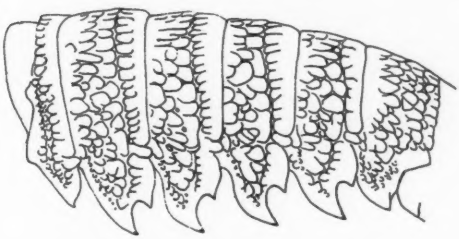


Figure 25.—*Jasus novaehollandiae*, southern spiny lobster, oblique view, side and upper surface of tail (adapted from George and Kensler, 1970).

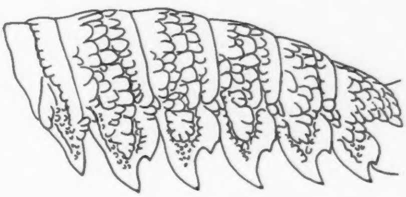


Figure 26.—*Jasus edwardsii*, red spiny lobster, oblique view, side and upper surface of tail (adapted from George and Kensler, 1970).

5a (2) First segment perfectly smooth, no squamiform sculpture on either side of transverse groove; following segments with sculpture restricted to 1 transverse row of large squames in front of transverse groove plus some very small squames before and behind this row, remainder smooth. Red with fine but dense reticulations of yellow. Juan Fernandez spiny lobster. Juan Fernandez and Islas de los Desventurados off Chile .... *J. frontalis* (H. Milne Edwards)†

5b First segment with forepart perfectly smooth but with sculpture present in narrow band behind transverse groove 6

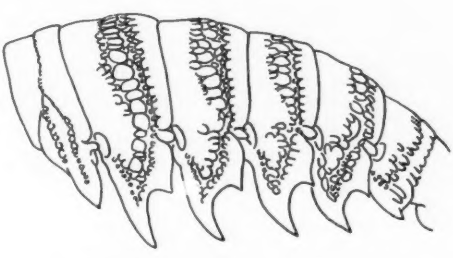


Figure 27.—*Jasus frontalis*, Juan Fernandez spiny lobster, oblique view, side and upper surface of tail (adapted from George and Kensler, 1970).

6a (5) Segments 2-6 each with large, broad squames arranged in 2 or 3 rows; rather wide transverse smooth area along front and back margins of each segment, even in fully stretched position; 2 unequal teeth on side plates directed backward. Reddish purple with small white spots; apexes of lateral segmental joints paler in color and pale spot near foremargins halfway between median line and lateral joints in rear segments, spots become elongate, forming oblique as well as median streaks on 6. South Atlantic around Tristan da Cunha, Gough Isl., and Vema Seamount .... *J. tristani* Holthuis†

6b Segments 2-6 sculptured as above except squames more numerous, both before and behind transverse groove on segments 2-5; 2 teeth on side plates, stronger foretooth straight, hind tooth blunt and distinctly serrate behind. Dark purple to reddish, smooth areas white speckled, larger tooth on side plates white tipped with "horn colored" point, lateral joints whitish. South Indian Ocean around St. Paul and Amsterdam Isl. .... *J. paulensis* Heller†

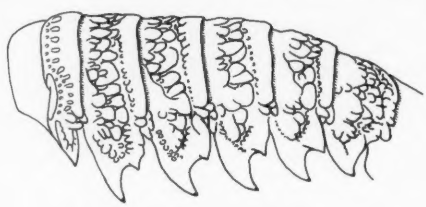


Figure 28.—*Jasus tristani*, Tristan da Cunha spiny lobster, oblique view, side and upper surface of tail (adapted from George and Kensler, 1970).

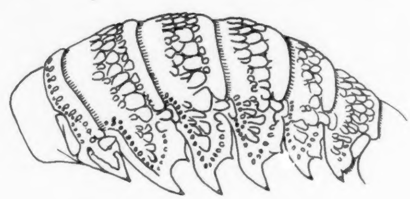


Figure 29.—*Jasus paulensis*, St. Paul spiny lobster, oblique view, side and upper surface of tail (adapted from George and Kensler, 1970).

Key to Species of *Linuparus*

1a Low but distinct spines or tubercles in median line on segments 1-4, small median tooth on hind margin of segments 5 and 6. Upper surface reddish-brown, side plates dull white. Western Indian Ocean from Kenya to Natal, 216-375 m .... *L. somniosus* Berry and George†

1b Low spines or tubercles in median line on segments 1 and 2, sometimes on 3, but absent on segment 4. No median tooth on hind margin of segments 5 and 6. Upper surface bright reddish to ivory 2

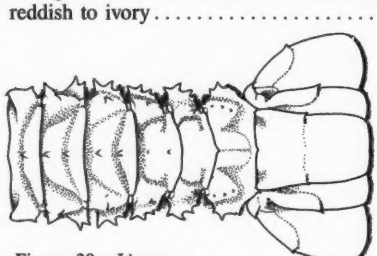


Figure 30.—*Linuparus somniosus*, upper surface of tail (from Holthuis, 1984).

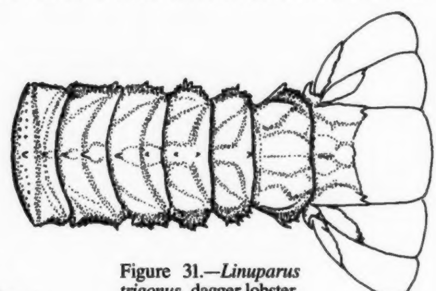


Figure 31.—*Linuparus trigonus*, dagger lobster, upper surface of tail (adapted from Ho and Yu, 1979).

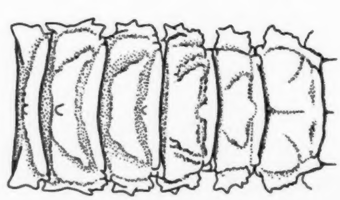


Figure 32.—*Linuparus sordidus*, upper surface of tail.

2a (*1*) Upper surface feebly granulated, or smooth and pitted, feebly setose. Mainly bright red with yellowish and brown or blue patches, ivory white in Australia. Dagger lobster. Japan, Yellow, East, and South China Seas, eastern Australia, 70-318 m .... *L. trigonus* (von Siebold)† (Color Fig. 78 f-g.)

2b Upper surface coarsely granulated and covered with short, thick setose pile. Yellowish. South China Sea to northwestern Australia, 310-328 m .... *L. sordidus* Bruce‡

Key to species of *Palinurus*

1a Segments with transverse grooves virtually nonexistent, represented by shallow depressions, hairs in grooves sparse and inconspicuous; side plates of segment 2 with 1 small spine on foremargin. Reddish mauve with contrasting irregular patches of ivory. Natal spiny lobster. Southwestern Indian Ocean, Natal to Mozambique, southeastern Madagascar, 0-530 m, usually 180-324 m .... *P. delagoae* Barnard*

1b Segments with transverse grooves on segments 2-5, interrupted at midline 2

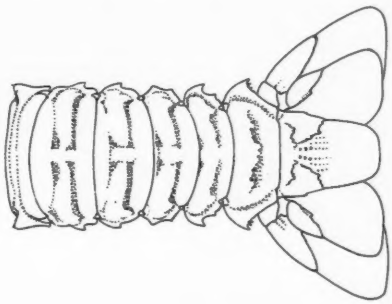


Figure 33.—*Palinurus delagoae*, Natal spiny lobster, upper surface of tail (from Holthuis, 1984); color pattern not shown.

2a (*1*) Segments 2-5 with transverse grooves rather irregularly broad, partly interrupted by incomplete median keel, grooves thickly hairy; side plates of segment 2 spineless on foremargin. Pinkish orange with irregular white patches. Gilchrist's spiny lobster. Coast of South Africa, False Bay to Natal, 55-102 m .... *P. gilchristi* Stebbing† (Color Fig. 78 h-i.)

2b Segments 2-5 with transverse grooves prominently interrupted by protuberance or non-grooved space at midline; grooves not hairy or very slightly hairy 3

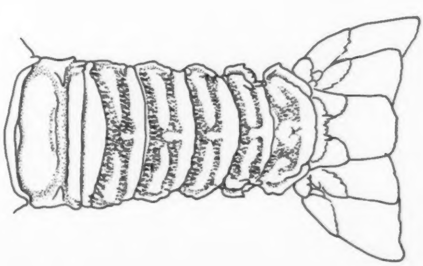


Figure 34.—*Palinurus gilchristi*, Gilchrist's spiny lobster, upper surface of tail (adapted from Berry and Plante, 1973); color pattern not shown.

3a (*2*) Side plates of segments 2-5 with 1-3 small spines on hind margin, that of segment 5 with 1 and sometimes a rudimentary 2nd spine. Upper surface more or less evenly pink, or violet-red to violet-brown, with marblings of white spots often strongly tinted with mauve. Pink spiny lobster. Eastern Atlantic from southwestern Ireland to southern Senegal, western Mediterranean, 60-400 (usually around 200) m . . . . *P. mauritanicus* (Gruvel)†

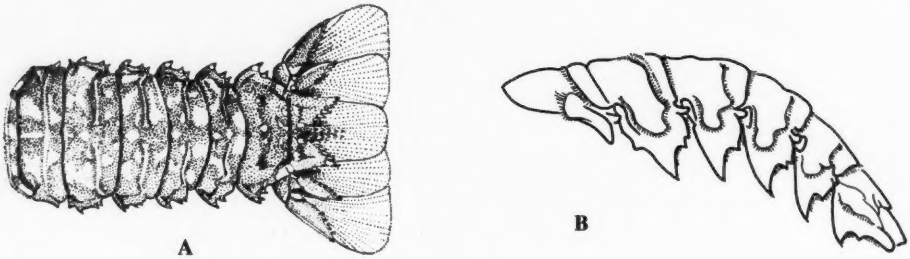


Figure 35.—*Palinurus mauritanicus*, pink spiny lobster: A, upper surface of tail (from Holthuis, 1981); B, side of segments 1-6.

3b Side plates of segments 2-5 with 3-4 small spines on hind margin, segment 5 with 3 spines 4

4a (*3*) Vermillion red violet, clear white spots symmetrically distributed on each side of midline, most numerous on hind part of each segment, and round or oval spot behind each groove. Cape Verde spiny lobster. Cape Verde Isl., 50-300 m . . . . *P. charlestoni* Forest and Postel† (May not be easily distinguishable from *P. mauritanicus*.)

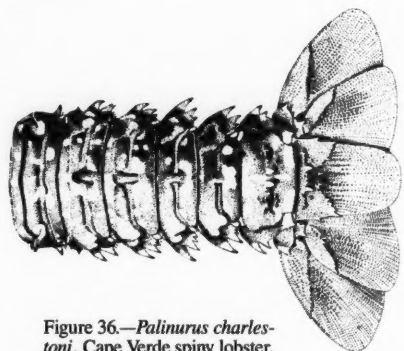


Figure 36.—*Palinurus charlestoni*, Cape Verde spiny lobster, upper surface of tail (from Holthuis, 1981).

4b Color somewhat variable. Brownish red to brownish violet, covered with darker spots and with symmetrical white or yellow blotches on segments 1-5. Common spiny lobster. Mediterranean, except southeastern part, and Atlantic coast of Europe from Western Norway, British Isles, and Morocco to Azores, below low tide mark to 70 m . . . . *P. elephas* (Fabricius)†

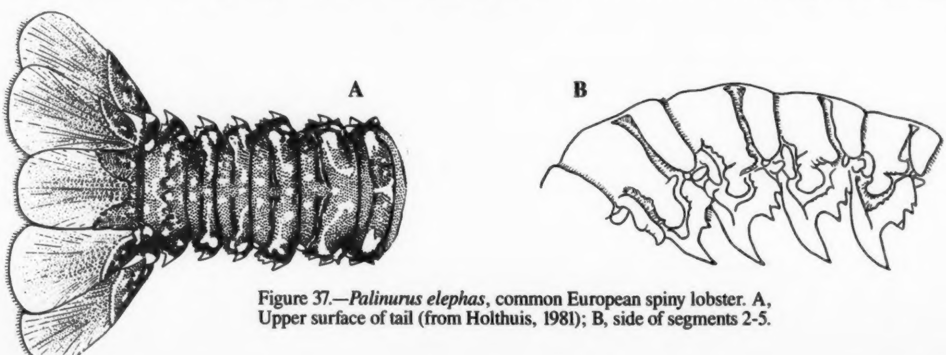


Figure 37.—*Palinurus elephas*, common European spiny lobster. A, Upper surface of tail (from Holthuis, 1981); B, side of segments 2-5.

Key to Species of Panulirus

1a Transverse groove on segments 2-5, sometimes faint; or sunken hairy areas, most prominent on segments 2-3 2

1b No transverse groove on segments 2-5, or shallow transverse hairy band on segments 2-3 only 14

2a (*1*) Transverse groove more or less continuous from side to side on at least some of segments 2-5, sometimes faint 3

2b Transverse groove obviously interrupted in middle on segments 2-5, or sunken area interrupted in middle on segments 2-3 11

3a (*2*) Foremargin of transverse grooves 2-5 scalloped. Olivaceous, bluish or brownish-red, speckled and dotted with yellow, lateral spot and indistinct transverse yellow line on each segment. Scalloped spiny lobster. Southwestern Indian Ocean and western Arabian Sea to East Indies, Japan and northwestern Australia, possibly Tahiti, to 90 m, usually 1-5 m .... *P. homarus* (Linnaeus)*
(Color Fig. 78 j.)

3b Foremargin of transverse grooves 2-5 not scalloped 4

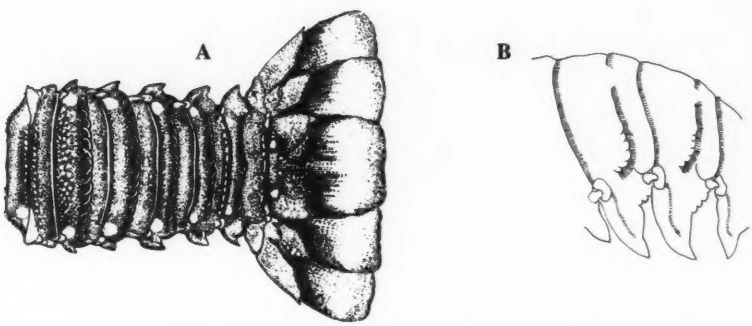


Figure 38.—*Panulirus homarus*, scalloped spiny lobster: A, Upper surface of tail; B, side of segments 2-3 (from Holthuis, 1984).

4a (*3*) Segment 2 with 2 transverse bands, front band may be broad and indistinct, fine, short, dense hairs sometimes present 5

4b Segment 2 with 1 transverse groove, either hairy or not so 6

5a (*4*) Foremargin of side plates on segments 2-5 lacking teeth. Pink to pale red, moderate number of spots. Western red lobster. Western Australia from Northwest Cape to Hamlin Harbor, usually 0-90 m, occasionally 120 m .... *P. cygnus* George* (Color Fig. 78 k-l.)

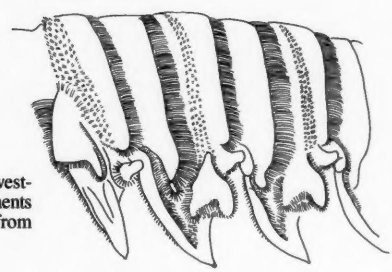


Figure 39.—*Panulirus cygnus*, western red lobster, side view of segments 1-3 and adjacent parts (adapted from George and Holthuis, 1965).

5b Foremargin of side plates on segments 2-5 bearing distinct small teeth. Bluish green, olive black, green brown or red, more or less mottled with yellow or with very fine dots on sides, largest spots on segment 1. Pronghorn spiny lobster, variegated crayfish, red lobster. Indo-Pacific from southeast Africa and Red Sea through East Indies and northern Australia, Japan and Polynesia, to Clipperton, Clarion, Cocos, Galapagos and Revilla Gigedo Isl., to about 16 m, usually 1-4 m .... *P. penicillatus* (Olivier)† (Color Fig. 78 m-n.)

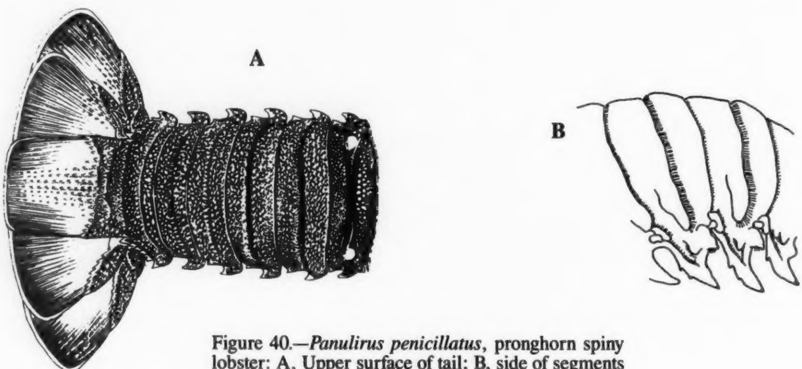


Figure 40.—*Panulirus penicillatus*, pronghorn spiny lobster: A, Upper surface of tail; B, side of segments 2-3 (from Holthuis, 1984).

6a (*4*) Transverse groove on segments 2 and 3 narrowly separated from groove on side plate 7

6b Transverse groove on segments 2 and 3 connected to groove on side plate 8

7a (*6*) Transverse groove of segment 4 narrowly separated from corresponding groove on side plate. Dark reddish, few pale spots on forward segments and lateral spot behind each segmental joint. Ise-ebi, Japanese spiny lobster. Japan, Ryukyus, Taiwan, Korea, east China .... *P. japonicus* (Von Siebold)†

7b Transverse groove of segment 4 joining corresponding groove on side plate. Dark blue, white spots on forepart of segment 1, following segments with row of pale dots on forepart, narrow white band along hind margin, and broader band in front of groove; lateral white spots behind segmental joints. Easter Island spiny lobster, langosta, crayfish, ura. Easter and Pitcairn Isl., to 5 m .... *P. pascuensis* Reed†

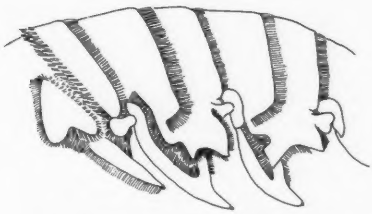


Figure 41.—*Panulirus japonicus*, Japanese spiny lobster, side view of segments 1-3 and adjacent parts (adapted from George and Holthuis, 1965).

Figure 42.—*Panulirus pascuensis*, Easter Island spiny lobster, side view of segments 1-3 and adjacent parts (adapted from George and Holthuis, 1965).

8a (*6*) Blue-green, thickly covered with bold light spots; foremargin of side plates 2-5 bearing very small teeth. Spotted spiny lobster, Spanish lobster, sand lobster. Bermuda, Bahamas, and Caribbean Sea to Brazil, to 20 m .... *P. gutattus* (Latreille)‡ (Color Fig. 78 o, 79 a.)

8b Transversely banded or spotted, some species with large ocellated spots to sides; foremargin of only segment 2 bearing very small teeth, sometimes smooth 9

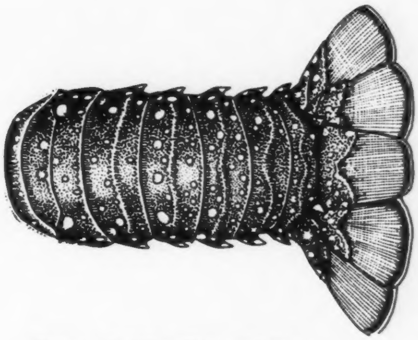


Figure 43.—*Panulirus guttatus*, spotted spiny lobster, upper surface of tail (from Manning, 1978).

9a (*8*) Yellow or reddish brown to green or bluish, conspicuous ocellated yellow spot to either side of each segment, largest on segments 2 and 6; tail fan with terminal broad black band. Segment 2 with transverse groove, often faint in middle section. Caribbean spiny lobster. Western Atlantic from Bermuda and North Carolina to Rio de Janeiro, Brazil, 2 rare occurrences on African Ivory Coast, to 90 m, rarely 450 m .... *P. argus* (Latreille)* (Color Fig. 79 b-c.)

9b Purple with transverse bands of yellow, or wine colored to indigo or purplish red, largest spots to side 10

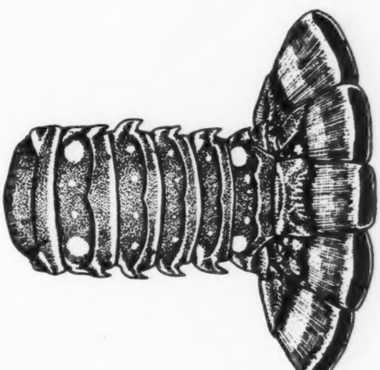


Figure 44.—*Panulirus argus*, Caribbean spiny lobster, upper surface of tail (from Manning, 1978).

10a (*9*) Purple with bold but pale transverse bands of yellow, single spot on each segment along either side. Hawaiian spiny lobster. Hawaii, to 140 m .... *P. marginatus* (Quoy and Gaimard)† (Color Fig. 79 d-e.)

10b Violaceous or indigo to purplish red or reddish brown, profuse scattering of small yellowish white spots, larger ocellated spot on each segment in row along side, tail fan reddish toward hind margin and bearing white marginal line in purple band. Longlegged spiny lobster, two subspecies, white whiskered and spotted-legged. Indo-West Pacific from Zanzibar to Japan, New Hebrides, and Tahiti, to 36 m, usually 1-18 m .... *P. longipes* (A. Milne Edwards)‡ (Color Fig. 79 f-g.)

Figure 45.—*Panulirus marginatus*, Hawaiian spiny lobster, side view of segments 1-3 and adjacent parts (adapted from George and Holthuis, 1965).

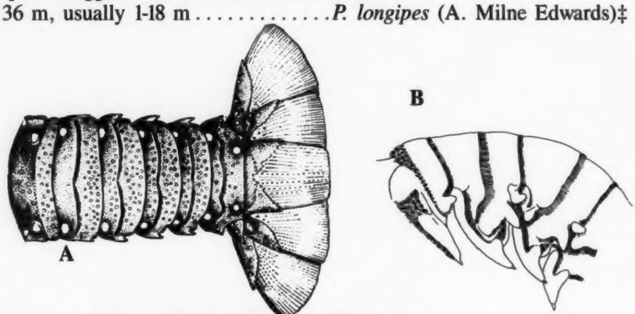


Figure 46.—*Panulirus longipes*, longlegged spiny lobster: A, side view of segments 1-3 and adjacent parts (adapted from George and Holthuis, 1965); B, upper surface of tail (from Holthuis, 1984).

11a (*2*) Side plates of segments 2-5 with no more than 1 large tooth on hind margin. Brown more or less strewn with small whitish spots except single larger spot at base of side plates. Brown spiny lobster. Atlantic islands; Fernando de Noronha, Atol de Rocas, St. Paul's Rocks, St. Helena, Ascension, Canary and Cape Verde Isl., also northeastern Brazil from Ceará to Pernambuco, shoreline to 35 m .....*P. echinatus* Smith‡

11b Side plates of segments 2-5 with series of small teeth on lobe of hind margin 12

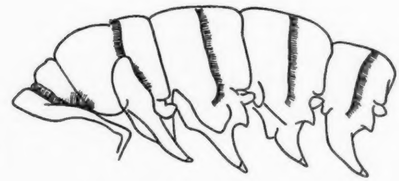


Figure 47.—Panulirus echinatus, brown spiny lobster, side of tail.

12a (*11*) Segments 2-6 with indistinct sunken hairy areas, forming broad groove interrupted in middle on 2 and 3. Drab or red without pale bands but with many fine spots, sides with short white vertical lines and conspicuous white spots on each segment; tips of side plates white; lower side of first segment bearing white spot surrounded by dark color on each half. Hong Kong spiny lobster. South China Sea, Shanghai to Hong Kong, Amoy ....*P. stimpsoni* Holthuis† (Sunken hairy areas on segments 2 and 3 of small to moderate sized *P. versicolor* (Latreille) and *P. regius* de Brito Capello resemble those of *P. stimpsoni*, but color greenish and strikingly banded; go to 13b, 18a, or 19b.)

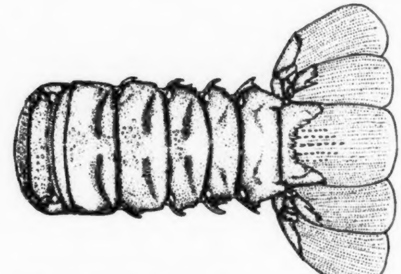


Figure 48.—*Panulirus stimpsoni*, Hong Kong spiny lobster, upper surface tail (adapted from Ho and Yu, 1979).

12b Segments 2-6 deeply or shallowly grooved (but not with sunken areas as above) 13

13a (*12*) Transverse grooves of segments 2-6 deep, broadly interrupted in midline, continuous with grooves on side plates of segments 2-6. Red to nearly black. California spiny lobster, red lobster. Central California to near southwest tip of Baja California Sur, usually 2-30 m, occasionally to 70 m ....*P. interruptus* (Randall)† (Color Fig. 79 h-i.)

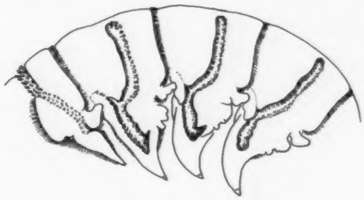


Figure 49.—*Panulirus interruptus*, California spiny lobster, side of tail.

13b Transverse grooves of segments 2-6 shallow, broadly interrupted in midline, not continuous with grooves on side plates of segments 2-3. Bluish or olivaceous green; transverse yellow band on each segment bordered with blue in front and on hind margin, or band of white bordered by dark green or brown band on hind margin, yellow or white spot near base of side plates; sometimes marked with violet. Royal spiny lobster. West Africa from Morocco at about lat. 28°N to beyond Cape Fria, Namibia, below low tide mark to 40 m, usually 5-15 m ....*P. regius* (de Brito Capello)† (Color Fig. 79 j-k.)

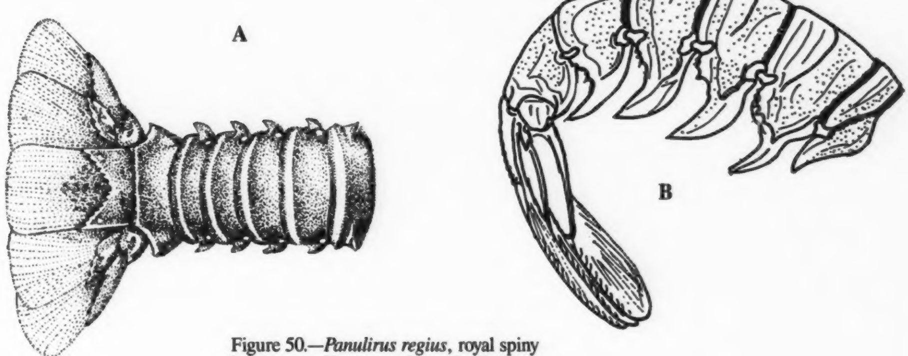


Figure 50.—*Panulirus regius*, royal spiny lobster: A, Upper surface of tail (from Holthuis, 1984); B, side of tail (adapted from Beaubrun, 1978).

14a (*1*) Yellow color on upper surface restricted to spots or marbling, no sharply defined continuous transverse bands of yellow 15

14b Distinctly yellow or whitish transverse band near hind margin of segments 1-3 or 1-6 16

15a (*14*) Color greenish; diagonal patches of bluish and yellow or white, and a broad dark band across middle of segments. Ornate spiny lobster. Indo-West Pacific; South Africa and Red Sea to Taiwan, Okinawa, and southern Japan, Indonesia, Melanesia, and Australia, 1-8, occasionally 25 m . . . . *P. ornatus* (Fabricius)† (Color Fig. 79 l-m.)

15b Segments 1-3 greenish on forepart, dirty red on hind part and provided with line of yellow dots near hind margin, yellow spots on sides; last 3 segments dull green with broad, deep red band on hind part, also with yellow dots. Smoothtail spiny lobster. Bermuda, southern Florida, Yucatan, and West Indies to northeastern Brazil, to 45 m . . . . *P. laevicauda* (Latreille)* (Color Fig. 79 n-o.)

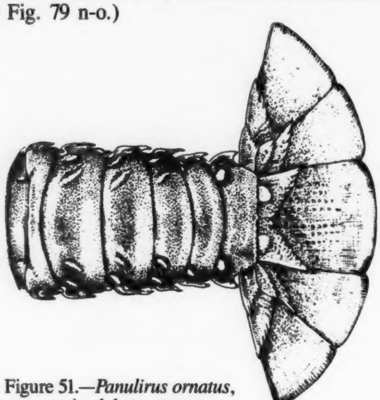


Figure 51.—*Panulirus ornatus*, ornate spiny lobster, upper surface of tail (from Holthuis, 1984).

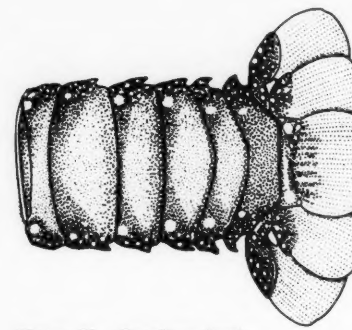


Figure 52.—*Panulirus laevicauda*, smoothtail spiny lobster, upper surface of tail (from Manning, 1978).

16a (*14*) Indigo blue with fine transverse line near hind margin of segments 1-3, segments 4-6 without transverse line but with bold and regularly placed yellow spots. Langosta, blue, or caribe lobster. Southwestern Baja California Sur, littoral of entire Gulf of California to western Gulf of Tehuantepec . . . . *P. inflatus* (Bouvier)‡ (Color Fig. 80 a-b.)

16b Greenish (sometimes) mixed with blue, brown, or black; transverse yellow or white stripe on all segments 17

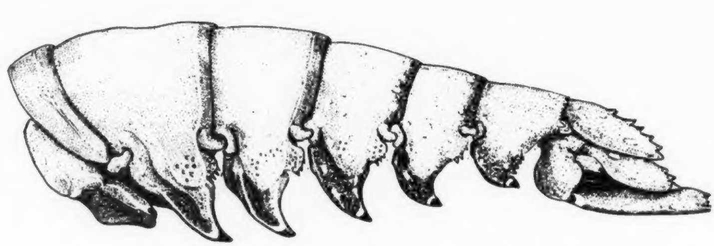


Figure 53.—*Panulirus inflatus*, blue or caribe lobster, side of tail (from Holthuis and Villalobos, 1961).

17a (*16*) Transverse pale band on hind margin of each segment or brown band with white line running through it. Mud spiny lobster. Indo-West Pacific, east Africa through East Indies, to Japan and northern Australia, to 90 m, usually less than 40 m . . . . *P. polyphagus* (Herbst)*

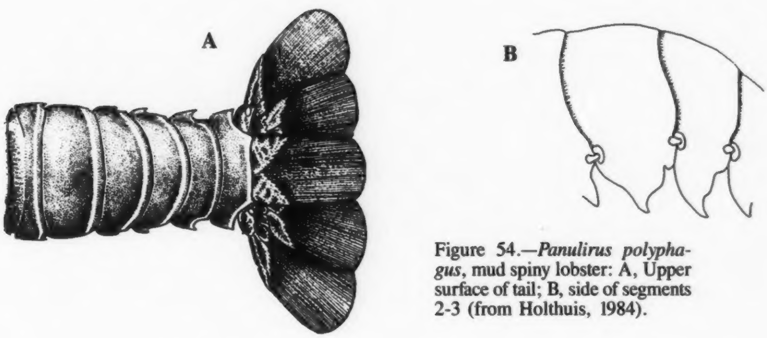


Figure 54.—*Panulirus polyphagus*, mud spiny lobster: A, Upper surface of tail; B, side of segments 2-3 (from Holthuis, 1984).

17b Transverse bold yellow or white stripe near hind margin of each segment bounded by dark band on either side 18

18a (*17*) Lacking yellowish spot at side of each segment or at base of middle member of tail fan. Painted spiny lobster. Indo-West Pacific, east Africa and Red Sea to Japan and Polynesia, to 16 m . . . . *P. versicolor* (Latreille)‡
(Color Fig. 80 c-d.)

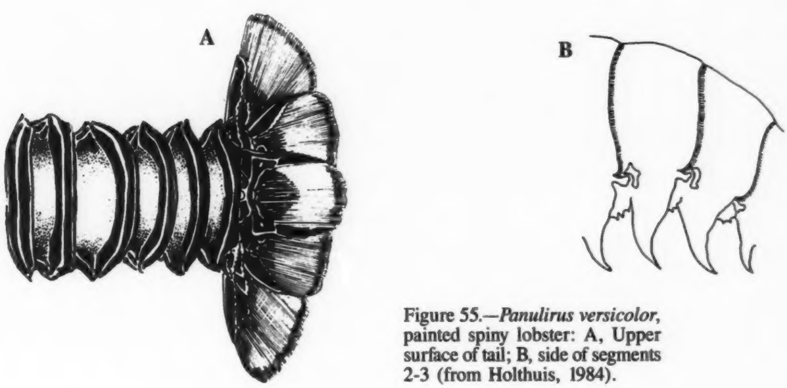


Figure 55.—*Panulirus versicolor*, painted spiny lobster: A, Upper surface of tail; B, side of segments 2-3 (from Holthuis, 1984).

18b Large yellowish spot at side of each segment and spots on middle member of tail fan 19

19a (*18*) Dark bluish or brownish green; whitish band on hind part of each segment flanked by darker band before and behind it, side plates with similar band connected to transverse bands on segments 2-5 and with white line on forepart of each and near segmental joint as well as foreside of segment 1; 4 basal spots in curved row across middle member of tail fan. Langosta verde, playa. Southern Sinaloa to northern Peru, Galapagos Isl., to 18+ m............*P. gracilis* Streets†
(Color Fig. 80 e-f.)

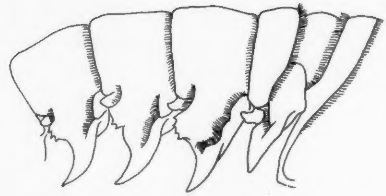


Figure 56.—*Panulirus gracilis*, langosta verde, side of tail.

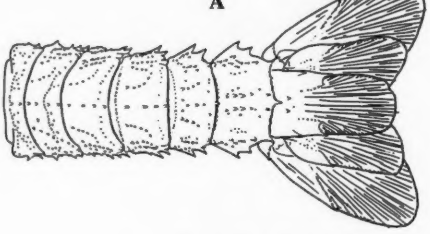
19b Dark band in front of transverse yellow band continued boldly onto side plates 1-5. Bluish or olivaceous green; tiny flecks of yellow across rear half of each segment and yellow spot near base of side plates; sometimes marked with violet; spots at sides on middle member of tail fan. Royal spiny lobster. West Africa from about lat. 23°N to beyond Cape Fria, Namibia, 40+ m.......................................very large *P. regius* (de Brito Capello)*
(Shallow transverse grooves or patches are obliterated in large adults making them appear to have almost smooth back plates.)
(Color Fig. 79 j-k.)

Key to Species of *Puerulus*

The species of *Puerulus* look like miniatures of *Linuparus*, but marginal spines on the side plates are 2 in number, rather than 3, and far longer in females than in males. The species cannot easily be distinguished on the basis of tails alone, but the color pattern of some species is distinctive. All are from the western Indo-Pacific.

1a Underside of segment 1 with transverse ridge bearing a moderately developed spine toward either side and a barely perceptible raised area to either side near midline; transverse ridges on underside of segments 2-5 lacking spines; side plates of segments 3-5 with front spine swept downward and backward, much longer in female than in male. Lesser Sunda Isl., Moluccas and Philippines, 520-683 m.....................................*P. velutinus* Holthuis‡

A



B

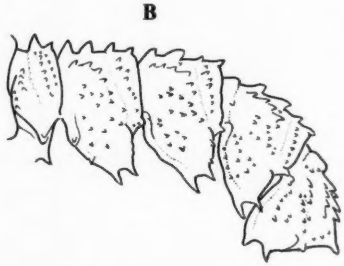


Figure 57.—*Puerulus velutinus*: A, Upper surface of tail; B, side of segments 1-5.

1b Underside of segment 1 with transverse ridge bearing 4 well-developed sharp spines; transverse ridges on segments 2-5 often with a spine to either side of midline 2

2a (*1*) Underside of segment 6 bearing 12 prominent, slender spines. Basically white with red patches and red at bases of white spines. Western Indian Ocean, East Indies, and Japan, 274-536 m . . . . *P. angulatus* (Bate)†

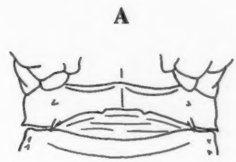
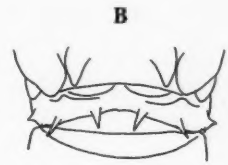


Figure 58.—Transverse ridge on underside of segment 1: A, *Puerulus velutinus*; B, *P. angulatus*.



2b Underside of segment 6 bearing 6 or 8 short spines or rudiments of them, sometimes almost completely absent 3

3a (*2*) Underside of segment 6 with a posteriorly directed pair of spines on hind margin; side plates of segments 3-5 with front spine swept downward and backward but each with broad indentation at base of front margin, longer in female than in male. Basically orange with bright red spines. Western Indian Ocean from Natal and Somali Republic to Saya de Malha Bank, 34-320 m . . . . *P. carinatus* Borradaile‡

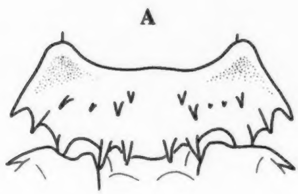
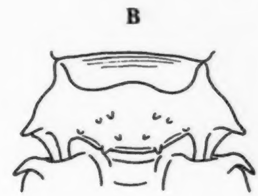
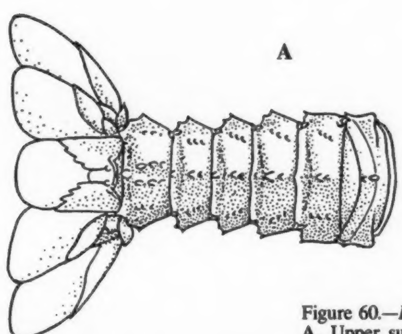


Figure 59.—Underside of segment 6: A, *Puerulus angulatus*; B., *P. sewelli*.



3b Underside of segment 6 with at most a pair of low tubercles on hind margin. Whip lobster. Gulf of Aden, Arabian Sea along India to Andaman Sea, 73-1,309 m . . . . *P. sewelli* Ramadan†



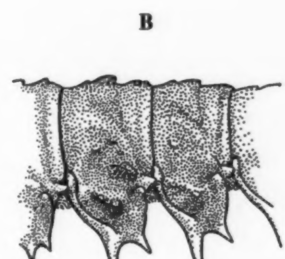


Figure 60.—*Puerulus sewelli*: A, Upper surface of tail; B, side of segments 3-4 (from Ramadan, 1938).

Key to Genera and Some Species of Flat, Locust, Slipper, and Spanish or Shovel-nosed Lobsters, Scyllaridae

1a Segments somewhat flattened but side plates directed downward 2

1b Segments so greatly flattened that side plates project laterally 3

2a (*1*) Segment preceding tail fan with small, acute, median spine extending beyond hind edge (may be broken). Brown, tan or gray, with transverse lines of granules and purple or bluish-black dots. Flathead locust lobster, northern shovel-nosed lobster, Moreton Bay bug. Queensland and northwestern Australia, Taiwan and Indonesia to Red Sea, Mediterranean (rare) and east Africa; 0-140 m . . . . *Thenus orientalis* (Lund)† (Color Fig. 80 g.)

2b Segment preceding tail fan with hind edge smooth, or with imperceptible median spine not extending beyond hind edge . . . . *Scyllarides*

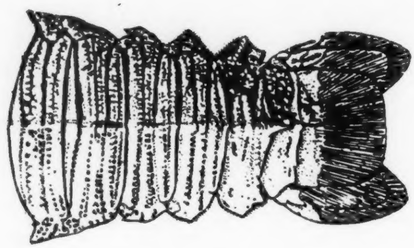


Figure 61.—*Thenus orientalis*, flathead locust lobster, upper surface of tail (from Holthuis, 1984).

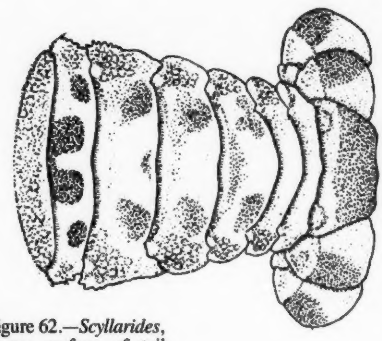


Figure 62.—*Scyllarides*, upper surface of tail (from Manning, 1978).

3a (*1*) Side plates of segment 2 with front edge spread almost straight to side, upper surface relatively smooth, not sculptured with pebble-like pattern . . . . *Ibacus ciliatus*‡ (Several species may be sold in undetermined amounts; among them are the pinkish fan lobster, *Ibacus ciliatus* (Von Siebold) and *I. ciliatus pubescens* Holthuis, Hong Kong, Philippines, Taiwan and Japan, about 70-225 m; the pale orange, pink-stippled, smooth fan lobster, *I. novemdentatus* Gibbes, southern Mozambique and Kenya to Taiwan and Japan, to 295 m; the pinkish, salmon-colored southern shovel-nosed lobster or Balmain bug, *I. peronii* Leach, southern Australia, 35-135 m.)

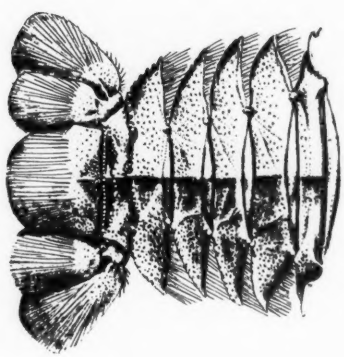


Figure 63.—*Ibacus*, fan or shovel-nosed lobsters, upper surface of tail (adapted from Holthuis, 1984).

3b Side plates of segment 2 with front edge angled obliquely forward, upper surface sculptured with pebble-like and scale-like pattern. Tan mottled with brown and red, but no enlarged red spots on segment 1. Sculptured slipper lobster. Atlantic Ocean from south Florida to Brazil, Indo-West Pacific from East Africa to Polynesia, 10+ m .... *Parribacus antarcticus* (Lund)‡ (Other species may be sold in undetermined amounts.)

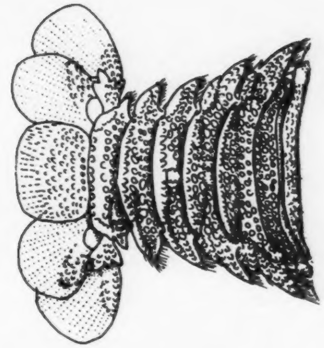


Figure 64.—*Parribacus antarcticus*, sculptured slipper lobster, upper surface of tail (from Manning, 1978).

Key to Species of *Scyllarides*, Flat Lobsters

1a Smooth part of segment 1 with no more than 1 red or reddish spot to each side of midline, median spot very diffuse if present at all 2

1b Smooth part of segment 1 without distinct spot, or more often with 3 or more red or reddish spots of varying size and intensity 4

2a (*1*) Red spots on segment 1 small and irregular; segments 3-4 distinctly humped. Humpbacked locust lobster. Mauritius, Red Sea, Malay Archipelago to Japan, Lord Howe Isl., off central eastern Australia (rare) .... *S. haanii* (De Haan)‡

2b Red spots on segment 1 bold and distinct; segments 3-4 not distinctly humped 3

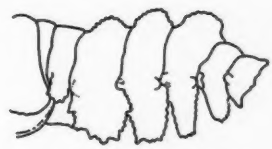


Figure 65.—*Scyllarides haanii*, humpbacked locust lobster, side view of tail (from Holthuis, 1984).

3a (*2*) Side plates of segment 2 with convex margins. Brazil .... *S. brasiliensis* Rathbun‡ (Color Fig. 80 h-i.)

3b Side plates of segment 2 with lower half of hind margin distinctly concave. Sao Paulo, Brazil .... *S. deceptor* Holthuis‡

Figure 66.—*Scyllarides brasiliensis*, side view of segment 2.

Figure 67.—*Scyllarides deceptor*, side view of segment 2.

4a (*1*) Segment 1 with 3 similar sized spots in line transversely 5

4b Segment 1 with spots either missing or not as above in size, shape, or intensity 7

5a (*4*) Segments 2-4 not strongly humped along midline. Brownish red to dark red. Red locust lobster. West Africa from northern Senegal to southern Angola, 2-70 m, rarely 200 m .... *S. herklotsii* (Herklots)‡
(Color Fig. 80 j-k.)

5b Segments 2-4 with humplike ridge along midline rather strongly set off from remainder of surface 6

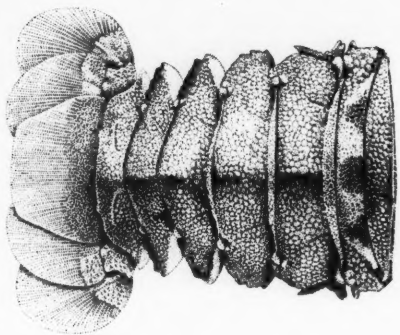


Figure 68.—*Scyllarides herklotsii*, red locust lobster, upper surface of tail (from Holthuis, 1981).

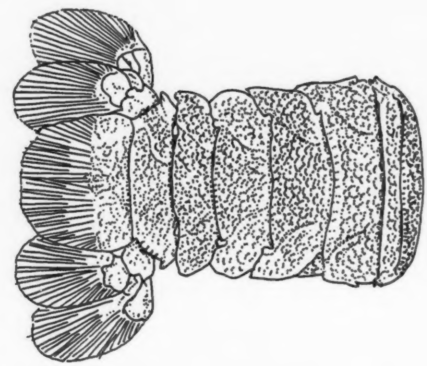


Figure 69.—*Scyllarides squammosus*, locust lobster, upper surface of tail (adapted from description of Holthuis, 1984).

6a (*5*) Segment 1 with median spot diffuse, not surrounded by ring of yellow; pale red blotches on body surface, marbled with brown or gray; side plates of segment 2 toothed on margin. Locust lobster. Indo-Pacific and north of Clipperton Isl., at least 3-53 m .... *S. squammosus* (H. Milne Edwards)‡

6b Segment 1 with spots placed widely apart and nearly equal in size; yellowish brown. Gulf of Aqaba and Red Sea .... *S. tridacnophaga* Holthuis‡

7a (*4*) Segment 1 with median spot (sometimes divided) more or less circular and bold 8

7b Segment 1 with median spot irregular; diffuse, missing, small, oval, broken into a patch of small spots, or broadly horseshoe-shaped 9

8a (*7*) Segments 2-4 with prominent, narrowed hump in midline; no partly hidden median red spot on smooth forward surface of segments 2-5. Ridged slipper lobster. Bermuda, Cape Lookout, N.C., to Florida and around Gulf of Mexico to Yucatan, 2-20 m, rarely to 100 m .... *S. nodifer* (Stimpson)‡

8b Segments 2-4 with low hump in midline scarcely set off from surrounding surface; small partly hidden median red or reddish spot on smooth forward surface of segments 2-5. Surinam, 42-80 m .... *S. delfosi* Holthuis‡

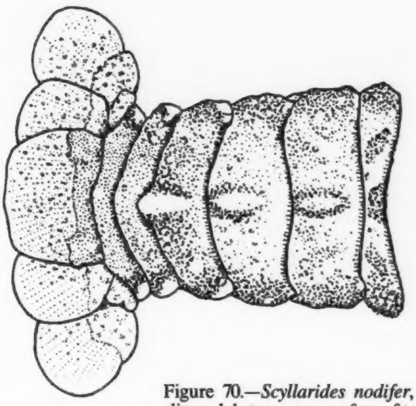


Figure 70.—*Scyllarides nodifer*, ridged slipper lobster, upper surface of tail (from Manning, 1978).

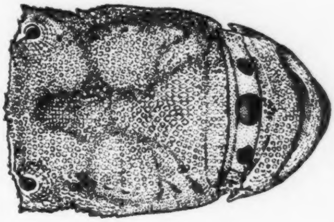


Figure 71.—*Scyllarides delfosi*, upper surface of body including head and part of tail (from Manning, 1978).

9a (7) Segment 1 with central bold, broadly horseshoe-shaped spot enveloping tiny and fainter median spot behind it. Spanish slipper lobster. Bermuda, Gulf of Mexico, south Florida and Caribbean Sea, less than 1 m to rarely 180 m .... *S. aequinoctialis* (Lund)‡ (Color Fig. 80 l-m.)

9b Segment 1 with median area not ornamented as above 10

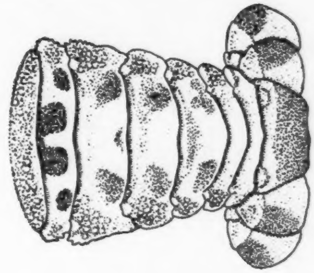


Figure 72.—*Scyllarides aequinoctialis*, Spanish slipper lobster, upper surface of tail (from Manning, 1978).

10a (9) Segment 1 with minute median spot but large lateral spot to each side, or lacking spots altogether; side plates of segment 2 with foremargin strongly convex, variably spined and tipped by backward pointing tooth, row of teeth diminishing from tip to base of hind margin. Reddish, dull brown, or greenish with oblique light brown slash toward sides. Cape locust lobster. Southern Africa, 87-380 m .... *S. elisabethi* (Ortmann)† (Color Fig. 80 n-o.)

10b Segment 1 with median spot variously shaped but not minute; side plates of segment 2 not as above, either toothed on foremargin, blunt tipped, or with large tooth on hind margin 11

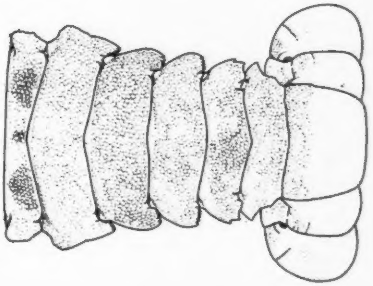


Figure 73.—*Scyllarides elisabethi*, Cape locust lobster, upper surface of tail (from Holthuis, 1984).

11a (*10*) Segment 1 with median oval dark red spot, often surrounded by clear ring of yellow; side plates of segment 2 with foremargin coarsely toothed but hind margin not so. Mediterranean locust lobster. Mediterranean Sea, Portugal to Gambia, Azores, Madeira, Canary and Cape Verde Isl., to 100 m, usually 4-10 m . . . . *S. latus* (Latreille)†

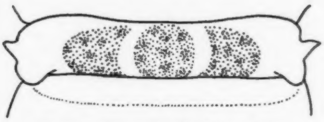


Figure 74.—*Scyllarides latus*, Mediterranean locust lobster, upper surface of segment 1 (adapted from Holthuis, 1981).

11b Segment 1 with median patch of spots, variable in density 12

12a (*11*) Median patch of red spots on segment 1 most dense in median area, often on yellowish background; segments 3-4 not definitely humped. Galapagos Isl., also off southern Baja California, to at least 15 m . . . . *S. astori* Holthuis‡

12b Median patch of red spots on segment 1 irregular and indistinct, not on yellow background; segments 3-4 definitely humped on upper side. Easter Isl. . . . . *S. roggeveeni* Holthuis‡

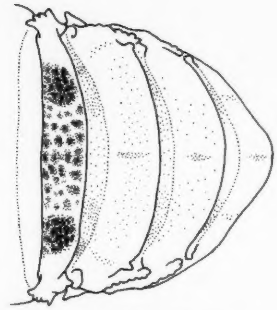


Figure 75.—*Scyllarides astori*, upper surface of segments 1-4.

Key to Species of Galatheidae, Squat Lobsters

Squat lobsters have very small tails, hence the distinguishing characters are minute and better seen with a magnifying glass than with the unaided eye. Common names in this group are not standardized and vary from country to country.

1a Segments 2, 3, and 4 with tiny spines on front edge of arched back plate. Yellow. Langostino amarillo. Central Chile, fishery extends from Caldera (lat. 27°S) to Calbuco (about lat. 42°S) at mainly 125-200 m, but occurs in shallower and deeper water . . . . *Cervimunida johni* Porter*

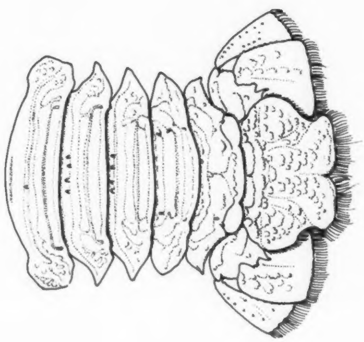


Figure 76.—*Cervimunida johni*, langostino amarillo, upper surface of tail.

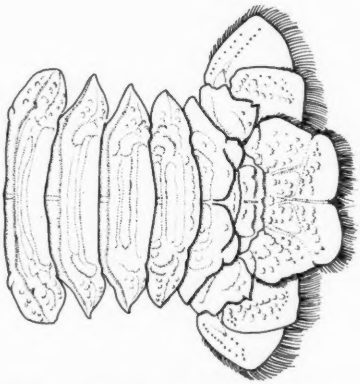


Figure 77.—*Pleuroncodes monodon*, camaroncillo roho or langostino colorado, upper surface of tail.

1b Arched back plates spineless .... *Pleuroncodes*

(Two species of this genus occur in vast swarms in the eastern Pacific; differences between them are obscure. The langostino colorado (red) or zanahoria (Chile), camaroncillo rojo (Peru), *P. monodon* (H. Milne Edwards)*, ranges from Lobos de Afuera Isl., Peru, to Ancud, Prov. of Chiloe, Chile; fishery same as given above for *C. johni*. The red or pelagic crab, *P. planipes* Stimpson, which has no present use in fisheries, occurs in extensive surface concentrations in the California Current off southern and Baja California, ranging for a distance of at least 1,000 miles southwestward; a bottom dwelling phase ranges along the western side of Baja California and in the lower Gulf of California at 60-365 m).

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The keys for identification contain information from a variety of sources other than those cited above. To avoid the complications of citing references in the keys, these sources as well as those given in the text are placed under selected subject headings: Color, biology, fishery statistics, general summary, systematics, and zoogeography. The list is biased toward fishery statistics, systematics, and zoogeography since these are the main topics of concern, but many of the references contain general information from each of the categories listed.

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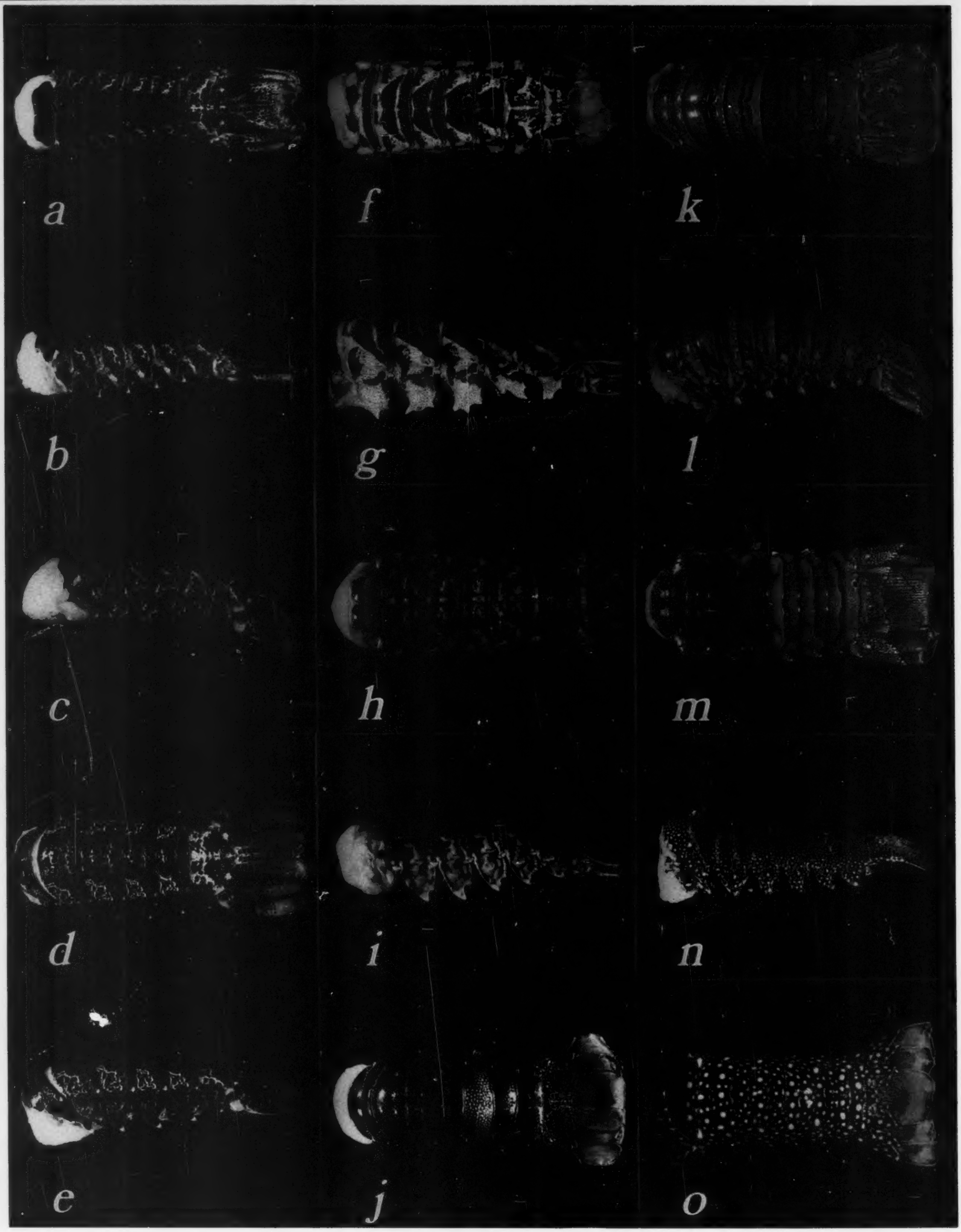

Figure 78.—Frozen lobster tails from market (hues vary): a-b, *Jasus lalandii*; c, *J. novaehollandiae*; d-e, *J. edwardsii*; f-g, *Linuparus trigonus*; h-i, *Palinurus gilchristi*; j, *Panulirus homarus*; k-l, *P. cygnus*; m-n, *P. penicillatus*; o, *P. guttatus*.

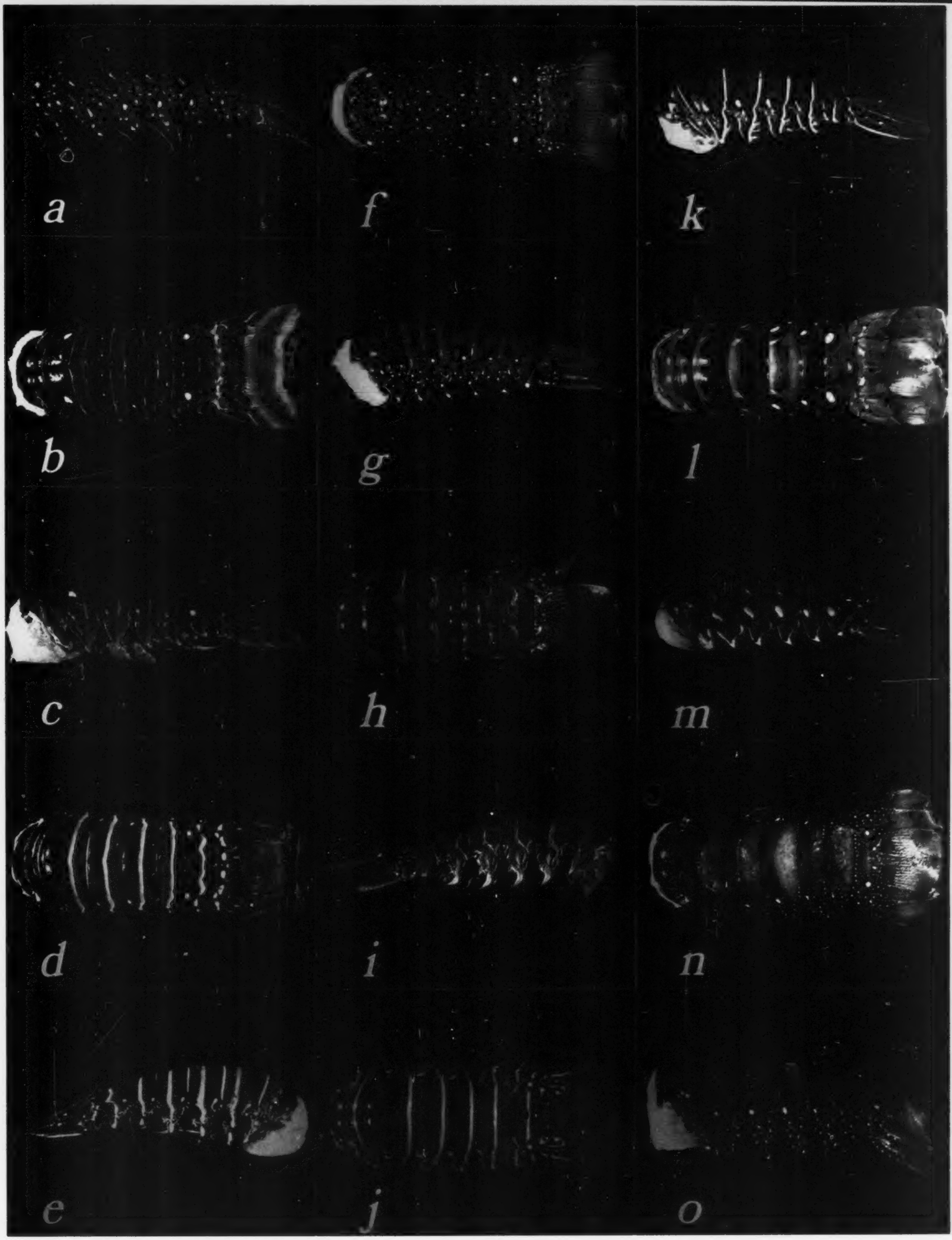

Figure 79.—Frozen lobster tails from market (hues vary): a, *Panulirus guttatus*; b-c, *P. argus*; d-e, *P. marginatus*; f-g, *P. longipes*; h-i, *P. interruptus*; j-k, *P. regius*; l-m, *P. ornatus*; n-o, *P. laevicauda*.

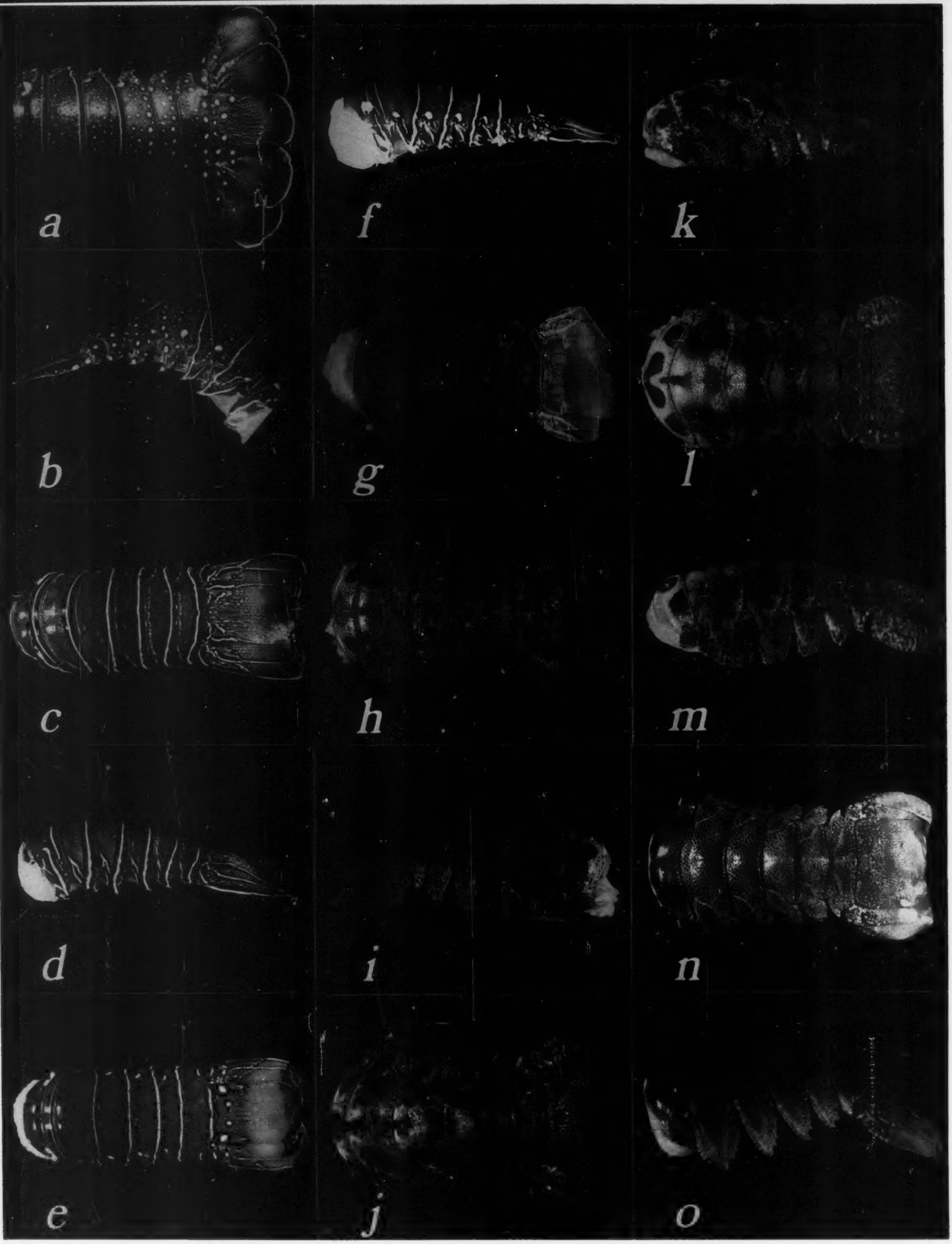

Figure 80.—Frozen lobster tails from market (hues vary): a-b, *Panulirus inflatus* (from M. Hendrickx); c-d, *P. versicolor*; e-f, *P. gracilis*; g, *Thenus orientalis*; h-i, *Scyllarides brasiliensis*; j-k, *S. herklotsii*; l-m, *S. aequinoctialis*; n-o, *S. elisabethi*.

A Mechanical Device to Sort Market Squid, *Loligo opalescens*

A. BOOMAN and R. PAUL SINGH

Introduction

Squid is an excellent source of protein and lacks the small bones which some consumers find objectionable in certain finfishes. Indeed, high quality squid is regarded as a gourmet food in many countries, particularly in the Orient and Mediterranean Europe. However, U.S. consumers are hesitant to buy whole squid because of its appearance and the need to clean it. Use of automatic skinning and eviscerating machines (Singh and Brown, 1980) is expected to improve the acceptance of squid by U.S. consumers, although several other problems related to processing and handling must be solved before the market for squid rings or fillets can be fully developed.

The fishery for market squid, *Loligo opalescens*, has considerable room for expansion[1]. However, the small size of this species, coupled with high manual processing costs and high ex-vessel prices in poor harvest seasons, can have a severe impact on the industry.

Automated sorting by size can make machine-packing of market squid more economical. It is also desirable when automatic cleaning machines are used because damaged squids or finfishes can be easily removed before entering the cleaning machines. In addition, better yields are possible if the cleaning machines are fed with uniform-sized squids.

Additional advantages accrue if males can be separated from females. Female squid can be sold whole, with roe (at higher prices), to Japanese markets where the roe is part of several traditional dishes. This study was made to determine the physical properties that affect squid sorting, and to develop techniques for mechanical sorting of *L. opalescens* by sex and size.

[1]Guide to underutilized species of California. 1983. Underutilized Fishery Resources Task, Tiburon Laboratory, Southwest Fisheries Center, NMFS, NOAA, 3150 Paradise Drive, Tiburon, CA 94920. SWFC Admin. Rep. T-83-01, second ed., 26 p.

ABSTRACT—Automatic sorting of market squid, Loligo opalescens, *is expected to facilitate machine-packing, thereby producing better yields and higher earnings. We found the tentacle-and-head:mantle length ratio suitable for sorting these squid by sex. That ratio was >0.80 for all males and <0.65 for all females, with a 99.5 percent confidence level. A laboratory-scale machine was built to sort squid by sex and size based on those ratios. The ratios increased for squid stored more than 1 day in ice.*

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Squid Characteristics

Squids are mollusks of the class Cephalopoda, and have eight sessile arms and two tentacular arms strongly attached to the head (Fig. 1). The mantle looks like a cone that surrounds and is attached to the visceral mass in a line at the back. The "pen" or "backbone"

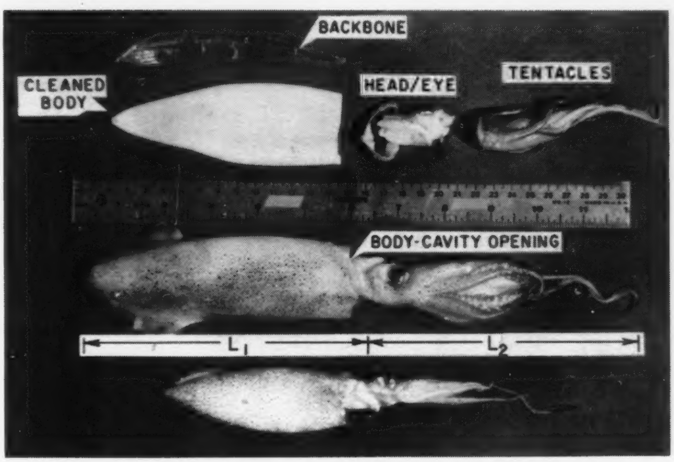


Figure 1.—Cleaned squid parts, above, and whole squid, below (from Singh and Brown, 1980).

is also situated in this line. Eggs and sperm sacs are located at the tip of the cone.

A full description of squid anatomy was published by Berry (1912). Although Berry stated "arms stout and rather short in the male, sometimes a little longer in the female," Fields (1965) showed that *L. opalescens* arms are proportionally longer in males ($\bar{x}$=165 mm) than in females ($\bar{x}$=150 mm).

Those sizes are small compared with such North Atlantic species as *L. pealei* and *Illex illecebrosus* (Berk, 1974), or the squids yari ika, *L. bleekeri*; kensaki ika, *L. edulis*; surume ika, *Todarodes pacificus*, and others caught by Japanese fishermen.

Market squid harvests in California average about 15,000 metric tons (t) per year (discounting El Niño years), but this might be increased to about 100,000 t annually (Voss, 1973) if demand increases.

Whole frozen market squid is inexpensive at retail compared with finfish or other seafoods ($3.57/3-pound box[2]), but its appearance and the need to clean it are the main reasons for its lack of popularity. Squid cleaned by hand would be very costly owing to high labor costs, and mechanization can significantly reduce squid processing costs.

Advantages of Sorting

Most female *L. opalescens* contain roe during the California fishery. Thus, their yield is low when cleaned as the roe may be lost. However, if the sexes are separated, the males can be cleaned by machine, providing a superior yield, and it is expected that the females can be sold whole, with roe, to foreign markets, especially Japan, at a better price.

Machine yields can be further improved by processing squids of uniform size and adjusting the knife position to provide maximum yield. Improper adjustment or processing squids of varying sizes can leave portions of the head attached to the tentacles or result in mantle cuts that are so small that the pen will not be detached in later operations.

[2]Three-pound box of market squid purchased by the authors at a large Davis, Calif., supermarket, Nov. 1984.

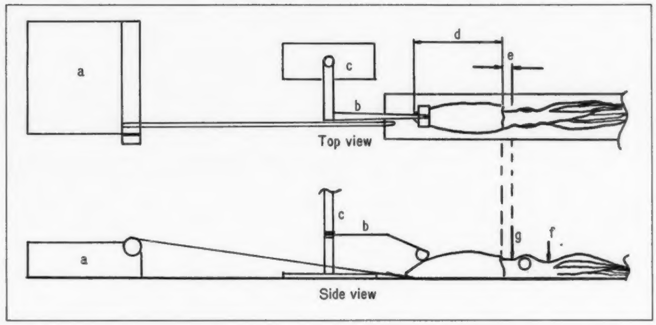


Figure 2.—Laboratory arrangement used to record squid profiles; a = chart recorder, b = cantilever beam, c = support, d = mantle length, e = elongation, and f and g = relative minimums.

Processing squid of uniform size can also facilitate packing of whole squid and result in a more uniform product with savings in both labor and equipment. Instead of packing by weight, packing could be done by the number of squid and of a given size. Packing can be easily automated to different degrees, or remain manual, but even packing by hand would be made faster.

Materials and Methods

Four lots of squid (A, B, C, and D) were used in this study. Lot A, whole, frozen *L. opalescens*, was purchased from two local supermarkets in 1983. Packages had a nominal weight of 0.454 kg (1 pound) and storage time was unknown. For all the tests with frozen squid, the boxes were allowed to warm up during 2 hours at room temperature, and were then opened and immersed in tap water. A small amount of fresh water was circulated until thawing was complete.

For Lot B, fresh squid samples in ice were collected at Monterey Bay, Calif., from the first boat to dock in June 1983. These samples were separated at the weighing station and layered with ice in an ice chest. Sufficient ice was used to cool the squid and maintain it at 0°C during the 3-hour transportation to the University of California laboratory in Davis. Ratios of tentacle-and-head to mantle length (hereafter called the tentacle:mantle length ratio) were determined the next morning. The total lengths (including tentacle, head, and mantle) measured for squid samples of Lot B ranged from 102 to 108 mm for males and from 110 to 112 mm for females (99.5 percent confidence level).

During 1984, the effects of El Niño made California market squid scarce. As a result for Lot C, fresh squid on ice was air-shipped from Oregon, but their size was also small, i.e., similar to California squid. The mantle length of 99 percent of the males was 86-91 mm. For 99 percent of the females, the mantle length range was 93-99 mm. For comparison purposes, Lot D consisted of frozen *Illex illecebrosus* shipped by air from the U.S. east coast.

Experimental Procedures

Profile Measurements

The laboratory arrangement for profile measurements is shown in Figure 2. Squid samples from Lot B were used in these experiments. The squid samples were placed by hand, backs up, on a polyethylene film. Each sample was caused to slide, mantle-end first, over the surface of the polyethylene film to simulate the position that squids take while sliding down. Small quantities of tap water were periodically splashed on the film to keep the surface wet so the squids could slide, but care was taken to keep the underside dry. The whole arrangement was located on a laboratory

bench. The polyethylene film was attached by cellophane tape to the chart of the recorder. A strain-gauge apparatus (Fig. 3) was used to record the the squid profile described by cantilever beam. With this arrangement squid profiles can be recorded regardless of chart speed. However to evaluate statistically the different body proportions of each sex, mantle length and tentacle-and-head length were manually measured.

The typical profiles of *L. opalescens* are shown in Figure 4 where differences between male and female tentacle lengths, and both the thickness and length of the female squid are easily observed. These profiles were obtained with the chart recorder and the cantilever beam arrangement (Fig. 2) using fresh squid that was held on ice for 3 days from Lot B.

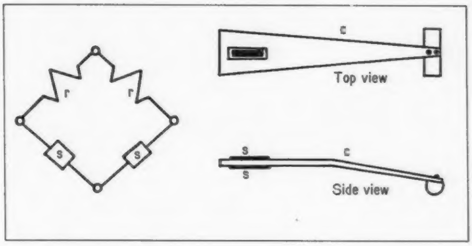


Figure 3.—Sensor used to record squid profiles, and bridge connections; c = cantilever beam, s = strain gauges, and r = resistances.

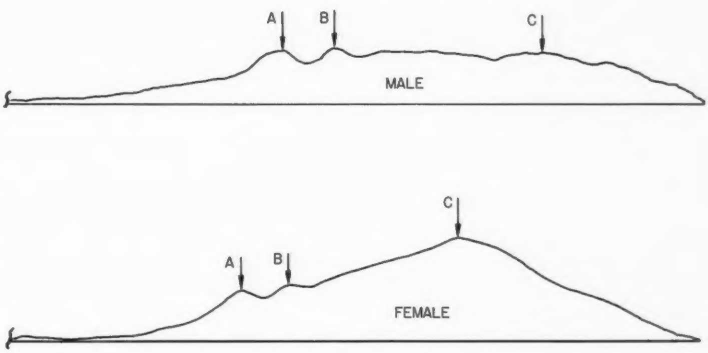


Figure 4.—Typical profiles of male and female *L. opalescens*, where A, B, and C = characteristic maximums for eyes, tentacle insertion, and mantle, respectively.

Tentacle:Mantle Length Ratios

Length measurements were made on a sample of 153 fresh squids taken in bulk from about 250 squids of Lot B. Tentacle-and-head length, and mantle length were also determined for each squid. The tentacle:mantle length ratio was then computed for the 153 squids. The measured samples were also examined individually whether they were male or female by dissecting each sample. The tentacle:mantle length ratio means computed were significantly different between males and females (0.8245 for males and 0.6418 for females). With a confidence level of 99.5 percent, the ratio is >0.8035 for all males and <0.6529 for all females.

The following day the tentacle:mantle length ratio was redetermined on a sample of 161 squid from Lot B. The means of this ratio was found to be higher for both males and females indicating that the squid undergo physical changes during storage.

From the first sample of 74 squid taken from Lot C, the tentacle:mantle length ratio was >0.8291 for 99.5 percent of the males and <0.7171 for the females. This upper limit for the ratio of the females is high because only 22 females were in the sample.

The tentacle:length ratio was also computed from manual measurements done on Lot D of the U.S. east coast samples of *Illex illecebrosus*. These squids had proportionally longer mantles and were much bigger than the *L. opalescens*. The mantles of the examined specimens were very thick, although all of them appeared to be in a postspawned condition. In proportion to the tentacles, the sizable arms were much longer and thicker. The tentacle: mantle length ratio was >0.7526 for the females, with a 99.5 percent confidence level, and <0.7457 for the males with the same confidence level. Although the possibility of males with greater tentacle:mantle length ratios or females with smaller ratios is small, the interval between the two ratios is less than 1 percent of the value of either ratio. This small difference means a very high resolution is necessary in any digital data acquisition system to be used. Also, with *I. illecebrosus*, the higher tentacle: mantle length ratio corresponds to the females, while on *L. opalescens* the higher ratio corresponds to the males. This preliminary analysis indicates that the approach to sorting presented here can be successfully used for *L. opalescens* but is unsuitable for *I. illecebrosus*.

Prototype Development

The significant difference between the tentacle:mantle length ratios suggested that an electro-mechanical system that

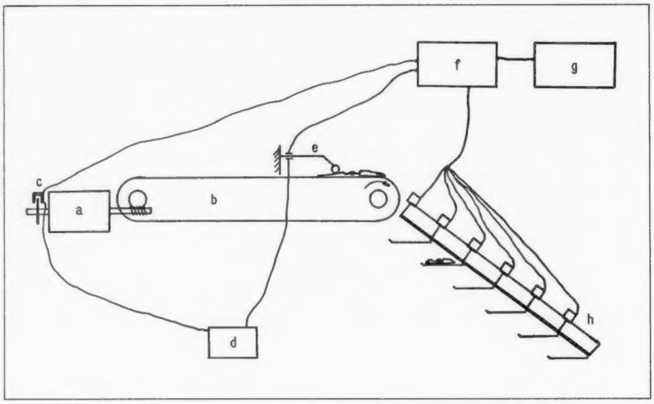


Figure 5.—Prototype machine; a = motor, b = conveyor belt, c = photoelectric unit with light emitting and detector diodes, d = 5V power supply, e = sensor, f = data acquisition and control unit, g = computer, and h = selector unit.

senses this length ratio could be useful in automatic sorting of market squid by sex.

The prototype developed in this study (Fig. 5) consisted of a cantilever beam mounted rigidly over a conveyor belt. Several materials were tested for the conveyor belt. All the flat belts tested failed to retain the squid under the roller when water was present. A perforated plastic belt was adopted so the water could drain through the holes. This belt (1.25 mm thick with round 2 mm diameter perforations 2 mm apart) gave satisfactory results. Cleaning was accomplished easily using water, brush, and soap.

Two strain gauges and two high quality resistors attached to the base of the cantilever beam were arranged as a Wheatstone bridge circuit (Fig. 5). Electricity was provided with a regulated 5V DC power supply. Output voltage was measured with an HP 3490A digital voltmeter (Hewlett Packard[3], Palo Alto, Calif.). The same power supply was used to provide an external trigger for the voltmeter with the signal required to take readings. A disc with two perforations was mounted on the shaft of the variable speed electric motor that drives the conveyor belt. A unit consisting of a light emitting diode and a detector diode was mounted so that the light was entirely blocked, except when the perforation matched with the emitter-to-detector line (Fig. 5). Thus, the readings from the voltmeter were synchronized with the displacement of the belt and were independent of the belt speed.

The digital output from the voltmeter was sent to a desk-top HP 9825T (Hewlett Packard) computer. As squid were detected, measured, and profiled, the values were entered, analyzed, and stored, starting with the tentacles. Charting profiles beginning with the tentacles was preferred because spurious relative minimums are more likely to appear within the mantle section (Booman, 1985). Maximum sampling speed of the HP 3490A voltmeter is three readings per second, and since nearly 100 readings are desirable to evaluate accurately the length of a large squid, 30 seconds were necessary for this particular step. A flowchart of the computer program is shown in Figure 6A and 6B.

Using this system, it was possible to sort squids by sex and size. The first tests were run using previously frozen squid (Lot A), since fresh squid was not available at the time. The samples were identified as males or females, and were sized, using arbitrary standards, as long, medium, and small, i.e., longest one-third, smallest one-third, etc.

The program for this voltmeter worked as follows: The light emitting and detecting head placed over the belt motor shaft signaled the HP 3490A multimeter to take readings at equal displacements of the belt. The computer read the multimeter when it was ready and compared the last reading with the constant in the memory that corresponded to the bottom-line deflection of the cantilever beam. When the value read was greater than the constant, it was stored in computer memory as the first reading. Consecutive values were stored until the detected deflection of the beam was no longer greater than the constant. When information storage ended, the computer started analyzing the data from the tentacle end. If the two minimums that corresponded to the tentacle-head section and the head-mantle section were not found, the program did not recognize the perturbation as a squid, printed a message, and started reading again. If the two minimums were found, the actual number of readings from the last recorded value until the second minimum were used to compute the tentacle length. The mantle length was compared with arbitrary standards, and the sample number, its size, sex, and the tentacle: mantle length ratio were printed out.

To increase the conveyor belt speed, we had to consider another voltmeter. The HP 3421A was selected because it is ten times faster than the HP 3490A when it is set to read voltages in the 0.1-10 V range. However, to use the HP 3421A, several modifications were necessary and are discussed by Booman (1985). A selector (Fig. 5) was constructed as a separate unit. This selector was driven by the HP 3050B data acquisition system.

To make the system fail-proof, certain ranges for the mantle and tentacles need to be incorporated. The same criterion was used to detect the squid that had been under excessive pressure during handling, and the females with little roe content.

[3]Mention of trade names or commercial products or firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

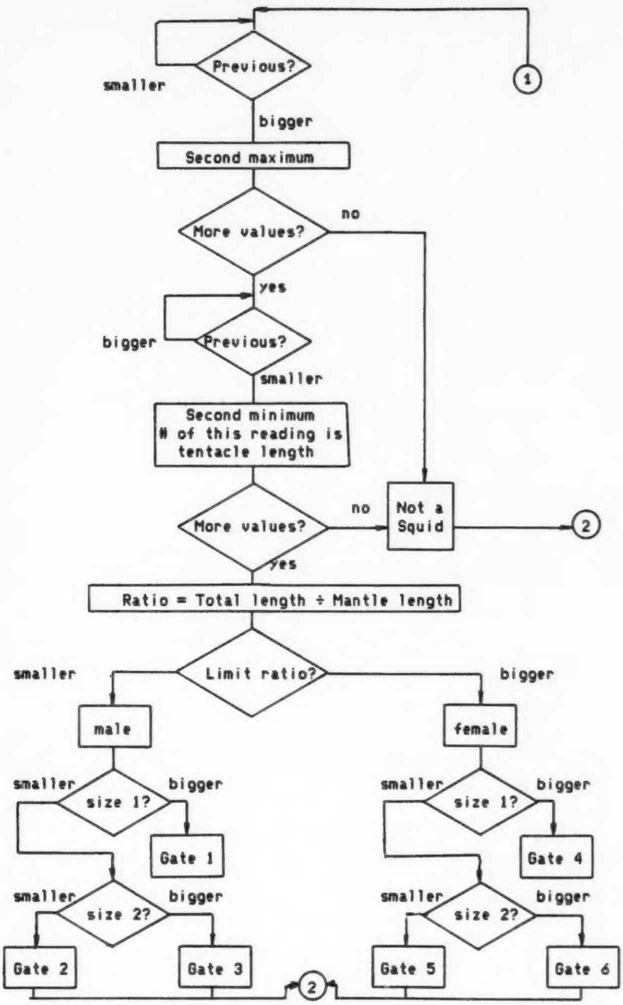


Figure 6A.—Flowchart of the computer program.

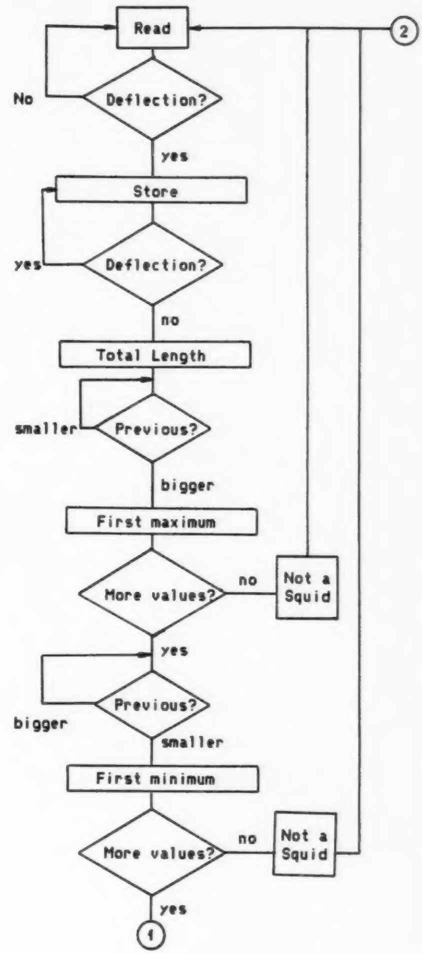


Figure 6B.—Flowchart of the computer program.

Tentacle:mantle length ratios and confidence intervals are shown in Figure 7 as a function of time from capture. The ratio measured by hand increased with time and the ratio measured by the prototype machine decreased. The reason for the opposite behavior of the means is that the mantle length is computed as the total length minus the length of the tentacles and head. The end of the head coincides with the location where the mantle portion starts in fresh squid. With time, the attachments of the internal organs to the mantle begin to relax, and a portion of the squid that was initially inside the mantle becomes visible as a long neck. Since the prototype machine uses the criterion of a relative minimum to find the point where the head ends, and this point is just at the end of the head, the neck that came off the mantle is considered part of the mantle by the prototype. A special procedure was developed to compare data obtained with the prototype machine with data obtained manually (Booman, 1985).

The tentacle length seen by the prototype also depends upon calibration. It was necessary to define a minimum

Figure 7.—Tentacle:mantle length ratios of *L. opalescens* during iced storage. Asterisks indicate lengths measured with the prototype machine; lines around data points indicate 99 percent confidence intervals.

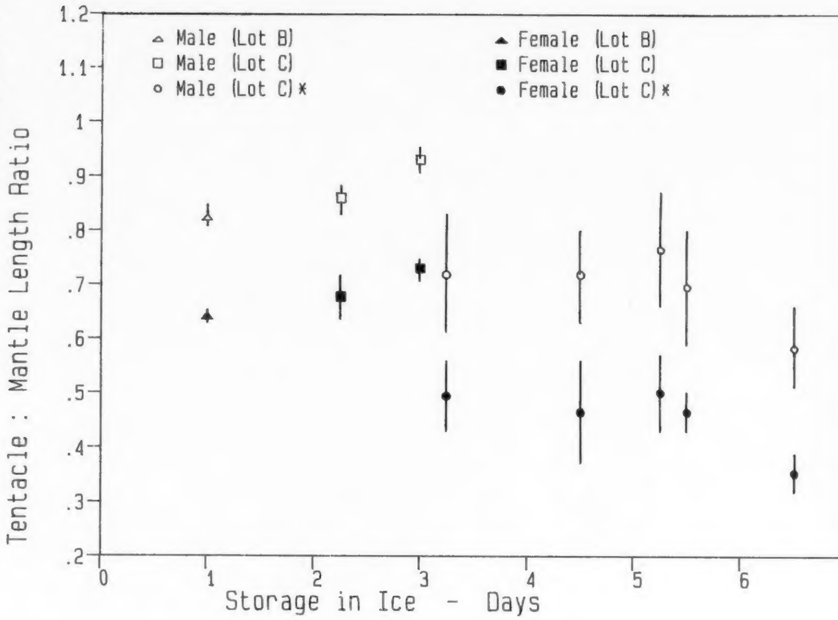
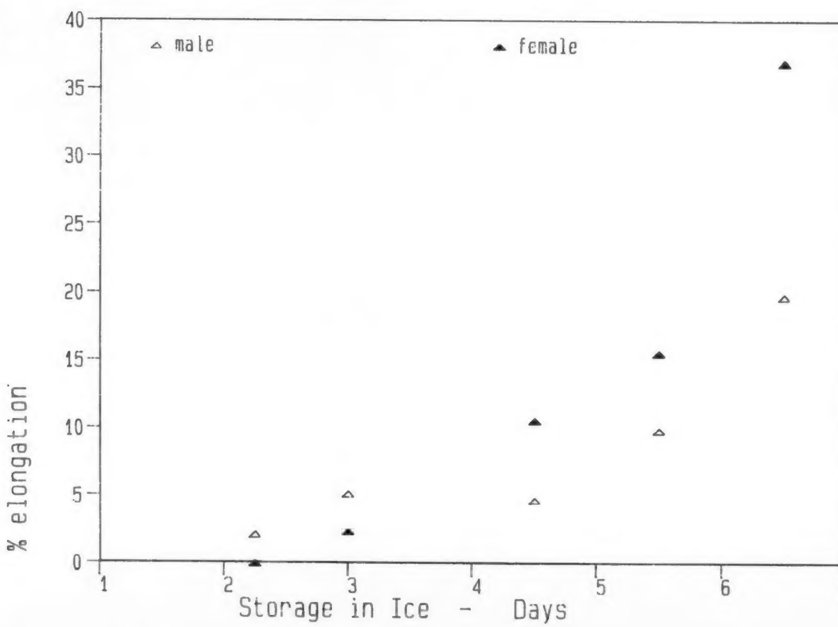


Figure 8.—Elongation of *L. opalescens* during iced storage.



thickness to be used by the machine as the presence of the tentacles, and this thickness must be set greater than the thickness of the tips of the two arms plus the amplitude of belt vibrations. It was also necessary to define a minimum noise level for the detection of the relative maximums and minimums. The elongation or increase in the total length of the market squid, which is most likely due to the physical changes that occur during storage, is shown in Figure 8 as a function of time from capture.

Conclusions

We found that market squid can be size-sorted using a mechanical device that contains a mechanical sensor, a microprocessor, and solenoid-driven gates. Such a full-scale operation will facilitate the processing and packing of market squid.

The tentacle:mantle length ratio for *L. opalescens* was determined to be 0.82 for males and 0.64 for females. With a confidence level of 99.5 percent, the ratio is >0.80 for all males, and <0.65 for all females. The tentacle:mantle length ratio remains constant for both sexes during the first day from capture. We also found that the elongation of *L. opalescens* during storage could be used for the constant monitoring of that aspect of squid quality in processing plants.

Acknowledgments

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Characterization of Proteolytic and Collagenolytic Psychrotrophic Bacteria of Ice-Stored Freshwater Prawn, *Macrobrachium rosenbergii*

R. J. PREMARATNE, W. K. NIP, and J. H. MOY

ABSTRACT—A microbiological analysis of ice-stored freshwater prawn, Macrobrachium rosenbergii, *was conducted to enumerate, isolate, identify, and test the proteolytic and collagenolytic activities of the psychrotrophic, proteolytic microflora. Twenty proteolytic cultures were isolated from 4-day ice-stored prawns using Azocoll-supplemented (AZOPCA) medium. These isolates were identified as belonging to* Pseudomonas *group I (fluorescent) species,* Pseudomonas *group II (nonfluorescent) species,* Alteromonas (Pseudomonas) putrefaciens, Flavobacterium *species, and* Cytophaga *species. Four of the identified isolates showing rapid and extensive proteolysis on AZOPCA medium at 5°C and 30°C showed collagenolytic activities on insoluble bovine collagen and prawn tissues. Proteolytic and collagenolytic activities were higher at 8°C than at 1°C and 5°C. Collagenolytic activity was higher with prawn tissues as substrate than with insoluable bovine collagen. These results also indicate that the proteolytic and collagenolytic microflora contribute very slightly to the development of mushiness in the initial stage of storage on ice (2-3 days) but contribute more extensively after 4 days.*

Introduction

Freshwater prawn, *Macrobrachium rosenbergii* culture is a relatively new and rapidly expanding industry in Hawaii. Annual production increased from 4,900 kg in 1974 to 13,600 kg in 1980 (Shang, 1981) and to 150,000 kg in 1985 (Fassler[1]). With this production volume, effective and economic postharvest handling (processing) of the prawns becomes critical.

Quality deterioration of the raw prawn under iced or refrigerated storage is characterized by softening (mushiness) which causes loosening and flaking of the cooked tissue of the prawn tail when touched or rubbed (Nip et al., 1985a). This mushy texture develops within 2-3 days in iced storage and is most pronounced in the proximal (first) tail section (adjacent to the cephalothorax). It progresses (downward) to the other sections of the tail with prolonged iced storage.

Little research has been done on the development of mushiness in freshwater prawns or other shellfishes during iced storage. Results indicate that one possible cause is the activity of a collagenolytic enzyme released by the hepatopancreas during postmortem autolytic processes (Baranowski et al., 1984; Nip et al., 1985b). The other possible cause which has not yet been investigated is the enzymatic activity contributed by the psychrotrophic proteolytic and/or collagenolytic microflora of the ice-stored prawn.

Neither the role of proteolytic/collagenolytic psychrotrophic microflora in the development of mushiness in *M. rosenbergii* nor the microflora of freshwater prawn produced in Hawaii have been reported. No previous work other than total and/or proteolytic bacterial counts have appeared in the literature (Angel et al., 1981; Shepherd, 1979; Waters and Hale, 1981). Several investigators have suggested or found that predominantly gram-negative psychrotrophic microflora develop in ice-stored fish and shellfish (Hobbs, 1983; Hobbs and Hodgkiss, 1982; Lee and Pfeifer, 1975; Nickelson and Vanderzant, 1976; Van Spreekens, 1977). These organisms belong to the genera *Pseudomonas*, *Alteromonas*, *Moraxella*, and *Acinetobacter.* The first two are known to be active spoilage organisms having proteolytic ability (Hobbs and Hodgkiss, 1982; Kazanas, 1967). However, only certain strains of pigmented *Pseudomonas* have been reported to exhibit collagenolytic activity (Adamcic and Clark, 1970; Waldvogel and Swartz, 1969). The objective of this study was to isolate, enumerate, and identify proteolytic and collagenolytic, psychrotrophic bacteria of 4-day ice-stored prawns and to test the collagenolytic and proteolytic activities of the isolated bacteria quantitatively.

[1]Fassler, R. Aquaculture Development Program, Hawaii Dep. Land Natural Resour. Personal commun., Jan. 1986.

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Materials and Methods

Media

Total Plate Counts: AZOPCA (Isolation Medium)

Plate count agar supplemented with 0.25 percent Azocoll[2] (Calbiochem Co., San Diego, Calif.) was used to isolate and enumerate proteolytic bacteria of fresh and ice-stored freshwater

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

prawns. Azocoll powder was sterilized by exposure of a 50 mg sample to 25 ml propylene oxide (Baranowski et al., 1984). Sterile Azocoll powder was mixed into sterile plate count agar (cooled to 50°C) before pouring into plates.

PCAP Medium

Plate count agar supplemented with 0.5 percent peptone (Difco, Detroit, Mich.) was used as the basal medium for antibiotic media, stock culture medium, and for master plates in replica plating (Corlett et al., 1965).

Differential and Related Media

Plates with PCAP medium as the basal medium containing antibiotics for testing different sensitivities were prepared by incorporating filter sterilized (0.22 μm millipore) antibiotics. Appropriate amounts of penicillin G(3 I.U./ml), tylosin (10 μg/ml, vancomycin (10 μg/ml) streptomycin (10 μg/ml), chloramphenicol (10μg/ml), (Sigma, St. Louis, Mo.) and a mixture of chloramphenicol (10 μg/ml) and streptomycin (10 μg/ml) were mixed individually into sterile PCAP medium (Corlett et al., 1965; Lee and Pfeifer, 1975). EMB, SS, McConkey, Staph110, Potato dextrose agar (acidified to pH 3.5), Hugh and Liefson's O/F medium (plate method), Simmon's citrate, and SIM media were prepared according to manufacturer's (Difco) instructions (Corlett et al., 1965; Lee and Pfeifer, 1975).

Oxidase Test

Oxidase test was performed on all isolates using oxidase reagent droppers (Marion Scientific).

Incubation of Prawns

Live freshwater prawns were obtained from a local supplier. The prawns were immobilized in an ice-slurry and stored aseptically on ice in an ice chest.

Isolation

Five 4-day ice-stored whole prawns were aseptically removed from iced storage, weighed, and blended separately in sterile Waring Blendors for 4 minutes at maximum speed with appropriate amounts of 0.1 percent peptone water (sterile, precooled) to obtain a tenfold dilution (blender dilution).

A 50 ml aliquot was removed from each prawn homogenate and pooled. A 1 ml sample was pipetted out of the pool and serially diluted, and 0.1 ml inocula from appropriate dilutions were spread-plated on AZOPCA plates in duplicate. After 10 days of incubation at 5°C, colonies showing proteolytic clear zones around them were picked from duplicate plates. Twenty colonies showed proteolytic activity. Inocula from each colony were streaked on a second set of AZOPCA plates for confirmation of proteolytic ability and for purification. Inocula from isolated colonies from each culture were picked up and spotted on PCAP master plates at predesignated positions (Corlett et al., 1965; Lee and Pfeifer, 1975).

Optimum Incubation Temperature

Optimum incubation temperature for use in the identification was determined by inoculating PCAP plates with the 20 cultures using the master plates for replication and incubating the replica plates at 5°C, 10°C, 15°C, 30°C, and 35°C. The temperature at which all isolates developed equally well was chosen as the optimum incubation temperature. This was found to be 15°C. All isolates grew equally well in 2-3 days at 15°C.

Identification

An identification procedure using replica plating was used (Corlett et al., 1965; Lee and Pfeifer, 1975). A PCAP master plate containing well developed colonies of each of the 20 isolates was used to inoculate a series of replica plates containing selective and differential media (antibiotic and nonantibiotic). Plates were incubated at 15°C for 2 days before interpreting the results using the identification schemes (Corlett et al., 1965; Lee and Pfeifer, 1975).

Tests for Proteolytic and Collagenolytic Activity

Culture Preparation

Identified cultures exhibiting rapid and extensive proteolysis on AZOPCA medium at 5°C were selected. Cultures were grown in 500 ml flasks containing 250 ml of tryptic soy broth. After 3 days of growth at 15°C, the culture suspension was centrifuged at $10^3 \times$ G (10,000 rpm) for 20 minutes, washed with peptone water once, recentrifuged, and suspended in 0.2 percent peptone water before using for inoculation.

Azocoll Assay for Proteolytic Activity

The procedure for proteolytic activity (Azocoll assay) provided by the Calbiochem Company was used with slight modification. As bacterial cultures were used instead of enzyme preparations, 10 ml of 0.2 percent peptone water was used to suspend the substrate (50 mg presterlized Azocoll) and the culture preparations in place of phosphate buffer. The 0.2 percent peptone water supported bacterial growth and production of proteolytic enzymes during the long incubation period at 1°C. No proteolytic activity was observed when phosphate buffer was used.

Centrifuge tubes with 50 mg of Azocoll powder each were sterilized using 25 ml propylene oxide. Ten milliliters of 0.2 percent peptone water was added to each tube and 1 ml inocula of individual bacterial culture in 0.2 percent peptone water were used to inoculate each tube. They were incubated for 4, 8, 12, and 16 days at 1°C. After incubation the tubes were centrifuged at $10^3 \times$ G (10,000 rpm) for 20 minutes, the supernatant containing the released azo dye was pipetted out and filtered (millipore 0.22 μm), and the absorbance measured at 520 nm.

Assay for Collagenolytic Activity

Fifty-milligram samples of presterilized freeze-dried prawn tissue per tube were used as the substrate. The procedure used in the Azocoll assay for sterilization and inoculation was followed. After incubating the samples for 3 and 6 days at 8°C, and 3 and 6 days at 1°C, the samples were centrifuged and the supernatant filtered. The filtered samples were assayed for hydroxyproline following the Woessner (1961) method and calculated as mg collagen

solubilized (Nip et al., 1981). The same procedure was used for the assay using presterilized insoluble bovine collagen as the substrate.

Results and Discussion

Total and Proteolytic Microflora

The total bacterial counts in freshwater prawn increased from 1.6×10^6 CFU/g at day 0 to 8.6×10^7 CFU/g at day 12 during iced storage (Table 1). This slight increase in total counts for the ice-stored prawns (*M. rosenbergii*) agreed with the Angel et al. (1981) study. It was obvious that the increase in numbers began after day 4 of iced storage and continued to increase during storage. However, the proteolytic counts did not begin to increase rapidly until after day 6 (Table 2), and they began to increase rapidly to 22 percent of the total bacterial counts by day 8, 42 percent by day 10, and to 87 percent by end of storage (day 12). This rapid increase in proteolytic microorganisms probably accounted partially for the putrid and objectionable odors coming from the prawns held in ice for more than 6 days.

Identification

The proteolytic bacteria isolated from 4-day ice-stored prawns are shown in Table 3. Five of the 20 isolates were identified as *Pseudomonas* Type I (fluorescent) based on the biochemical tests and physiological responses to differential/selective media (Corlett et al., 1965; Lee and Pfeifer, 1975).

Three isolates were identified as *Pseudomonas* Type II (nonfluorescent) (Corlett et al., 1965; Lee and Pfeifer, 1975).

Three organisms were identified as *Alteromonas* (*Pseudomonas*) *putrefaciens* as they had many characteristics in common with both *Alteromonas putrefaciens* and *Pseudomonas putrefaciens*. Since a DNA base pair ratio analysis was not done to differentiate the low G+C mol % (49 percent) containing *A. putrefaciens* from the high G+C mol % (58 percent) containing *P. putrefaciens*, it was named *Alteromonas* (*Pseudomonas*) *putrefaciens* (Parker and Levin, 1982).

Table 1.—Total aerobic psychrophilic counts (on AZOPCA medium) from fresh prawns and ice-stored prawns.

Iced storage (days)	Total aerobic psychrophilic counts[1] (CFU/g)		
	5°C	10°C	15°C
[2]0	1.6×10^6	1.8×10^6	4.7×10^6
4	1.6×10^6	2.1×10^6	3.0×10^6
6	5.0×10^6	3.4×10^7	1.9×10^7
8	8.8×10^6	5.6×10^7	6.6×10^7
10	5.8×10^7	8.2×10^7	8.8×10^7
12	8.6×10^7	8.6×10^7	9.0×10^7

[1]Values are averages of four trials (for fresh prawn samples) and two trials (for 4 days and 6 days ice-stored prawns). Three prawns were analyzed separately for each trial.
[2]Fresh.

Table 2.—Percentage of proteolytic microflora (on AZOPCA medium) from fresh and ice-stored prawns.

Iced storage (days)	Percentage of proteolytic colonies[1] (%)		
	5°C	10°C	15°C
[2]0	5.4	5.8	5.6
4	6.1	6.1	5.6
6	6.1	6.2	6.4
8	22	23	21
10	42	42	[illegible]
12	87	86.5	86.5

[1]Values are averages of three trials (for fresh prawn samples) and two trials (for 4 days and 6 days ice-stored prawns). Three prawns were analyzed separately for each trial.
[2]Fresh.

Table 3.—Identification of isolated proteolytic psychrotrophic microflora.

Isolate number	Identification
1, 5, 6, 7, 20	*Pseudomonas* group I (fluorescent)
11, 13, 16	*Pseudomonas* group II (non-fluorescent)
3, 8, 10	*Alteromonas* (*Pseudomonas*) *putrefaciens*
2, 4, 12, 14, 15, 17, 18, 19	*Flavobacterium* sp.
9	*Cytophaga* sp.

Proteolytic and Collagenolytic Activity

Four identified cultures belonging to *Pseudomonas* Group 1, *Pseudomonas* Group 2, *Alteromonas* (*Pseudomonas*) *Putrefaciens*, and a salt tolerant *Flavobacterium* exhibited rapid and extensive proteolysis on AZOPCA medium at 5°C (Table 4). At 1°C the cultures showed little activity until day 8 of incubation, after which the activity increased rapidly and reached a high level by day 12 of incubation.

Collagenolytic activity of the cultures was determined by the ability to solubilize insoluble bovine collagen (Type I, Sigma Co.) and collagen in prawn tissue. Tables 5 and 6 show the solubi-

Table 4.—Proteolytic activity of bacterial cultures at 1°C, measured as the increase in absorbance at 520 nm.

Isolate no.[1]	Absorbance[2] at 520 nm			
	4 days	8 days	12 days	16 days
4	0.07	0.09	0.20	0.28
5	0.19	0.20	0.25	0.35
8	0.21	0.23	0.36	0.61
16	0.20	0.21	0.26	0.38

[1]Concentrations of inocula are 2.1×10^6, 3.2×10^7, 3.8×10^7, and 4.0×10^7 cells/ml for isolates 4, 5, 16, and 8, respectively.
[2]Absorbance values are averages of four replicates.

Table 5.—Amount of hydroxyproline released from insoluble bovine collagen by proteolytic/collagenolytic bacterial cultures at various temperatures.

Isolate no.[1]	Temperature	Hydroxyproline[2] released (mg/g collagen)	
		3 days	6 days
4	8°C	1.50	3.70
5	8°C	4.35	6.70
8	8°C	5.55	7.60
16	8°C	3.70	7.40
4	1°C	0.75	2.85
5	1°C	3.00	6.50
8	1°C	4.70	7.60
16	1°C	3.55	7.25

[1]Concentrations of inocula are 5.2×10^6, 2.0×10^7, 3.5×10^7, and 3.8×10^7 cells/ml for isolates 4, 5, 16, and 8, respectively.
[2]Values are averages of three replications.

Table 6.—Solubilization of collagen in prawn tissues by proteolytic/collagenolytic bacterial cultures at various temperatures.

Isolate no.[1]	Temp.	Amount of collagen solubilized[2] (mg/g tissue)	
		3 days	6 days
4	8°C	0.103	0.208
5	8°C	0.330	0.370
8	8°C	0.363	0.435
16	8°C	0.278	0.375
4	1°C	0.055	0.160
5	1°C	0.200	0.375
8	1°C	0.253	0.445
16	1°C	0.190	0.370

[1]Concentrations of inocula are 5.2×10^6, 2.0×10^7, 3.5×10^7, and 3.8×10^7 cells/ml for isolates 4, 5, 16, and 8, respectively.
[2]Values are averages of three replicates.

lization of insoluble bovine collagen and collagen in prawn tissue by the four cultures at 1°C, and 8°C, respectively. Definite proof of collagenolytic activity was shown by the solubilization of collagen in prawn tissue and insoluble bovine collagen by the cultures at the lower incubation temperature (1°C) which is the most pertinent temperature as it is the closest to the iced-storage temperature. At higher temperatures (8°C), higher amounts of prawn collagen and insoluble bovine collagen were solubilized. The amount of solubilized insoluble bovine collagen was lower than amounts of solubilized collagen in the prawn tissue. This is possibly due to the specificity of the collagenolytic enzyme to prawn collagen and not to bovine collagen.

Proteolytic enzymes and motility are extremely important to bacteria in penetrating the muscle tissue. Gill and Penny (1977) showed that a proteolytic strain of *Pseudomonas fluorescence* penetrated a 2 cm block of meat (bull muscle) in 6 days at 5°C. The proteolytic and collagenolytic *Pseudomonas* species, *Alteromonas* (*Pseudomonas*) *putrefaciens*, and the salt tolerant *Flavobacterium* species isolated from the 4-day iced prawns were also motile. It is likely that these bacteria could have penetrated the prawn tissues and began degrading the inner muscle tissues by the production of proteolytic and collagenolytic enzymes and contributed to the mushy texture. Mushiness in the prawn tails has occurred, however, in 2-3 days of iced storage (Nip et al., 1985a). Since the collagenolytic and proteolytic bacteria did not reach a high percentage of the population until after day 6 of storage, significant bacterial degradation of tissue cannot be expected during the first 2-3 days.

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Deep-Sea Camera Records Hawaiian Fish Resources

A recently acquired deep-sea camera has been used to survey fishery resources at Penguin Bank off Molokai, Hawaii, reports Richard S. Shomura, Director of the NMFS Southwest Fisheries Center's Honolulu Laboratory. The camera was set on the ocean floor in 404 feet of water during a cruise of the NOAA ship *Townsend Cromwell* which was completed on 18 April. The surveys were conducted near areas where three artificial reefs have been placed by NMFS researchers.

Bait placed in front of the camera attracted animals from the surrounding water, and the camera, prepared by NMFS Fishery Biologist John T. Harrison, took a picture every minute for 2 hours. Although aweoweo were the only food fish attracted to the camera, other creatures such as puffers, eels, and crabs were attracted to the bait and small shrimp were seen in almost every photograph.

The shrimp, too tiny to be used as food directly by man, may be an important energy source for commercially valuable fishes. The deep-sea camera will be a useful tool for future research by the National Marine Fisheries Service, allowing views of areas difficult to see with divers or to sample with nets. The camera can be set at depths as great as 20,000 feet.

Under the supervision of Chief Scientist Bruce C. Mundy, the *Townsend Cromwell* cruise also included trap surveys at the Penguin Bank area and studies of the distribution of larval fishes near Oahu. Fish, shrimp, and lobster traps were set in the vicinity of the artificial reefs to determine what types of animals were in the area. While previous observations of the reefs from the University of Hawaii's submersible *Makali'i* have revealed concentrations of fish at the reef, little is known about the numbers of animals on the surrounding bank. The recently completed trap survey found no commercial sized shrimp and few lobster, crab, or fish. Most of the fish were taape, an abundant species initially introduced to Hawaii in 1955.

The third of four planned studies of the distribution of larval fishes at Oahu was also completed during the cruise; studies have been done during the autumn, winter, and spring. The goal of this work is to better understand how the very youngest stages of fishes, might be affected by Ocean Thermal Energy Conversion (OTEC) power plants planned for the islands.

New Reporting System for Western Pacific Fisheries

How much of this fish is landed? Is the fishery in danger? What important food fish is abundant in June? Where is it available? Can I afford to import it? These are the kinds of questions fishery managers, producers, and processors must answer every day.

To help make better decisions concerning fisheries of the central and western Pacific, David C. Hamm, a computer systems analyst at the NMFS Southwest Fisheries Center's Honolulu Laboratory in Hawaii has worked with numerous Pacific island fishery agencies in creating an information network capable of providing data to decision makers on a timely basis.

Before Hamm became involved about 5 years ago, collection of useful information in many areas was minimal, automated processing of data by island fishery agencies outside Hawaii was nonexistant, and dissemination of information was rare. By gaining the cooperation and support of Pacific island fishery agencies, Hamm has been successful in implementing a Southwest Fisheries Center program to improve these conditions.

The Pacific island fishery agencies have improved and standardized data collecting systems and have begun processing and sharing information by use of computers. Fishery data bases have been established at each island agency and at the Honolulu Laboratory. Hamm recently began coordinating the production of a new series of reports designed to distribute information on commercial landings of species caught around Hawaii, American Samoa, Guam, and the Commonwealth of the Northern Mariana Islands. Monthly and annual summaries of pounds, dollar value, and average price are reported for each species.

According to Richard S. Shomura, Director of the Honolulu Laboratory, Hamm's report gives an overall view of the fisheries. Shomura noted, "This report provides fisheries managers with vital information about the seasonality and relative abundance of fish, which in turn helps them formulate plans for managing the resources. The report will also be valuable to the fishing industry in the Pacific by improving their marketing and importing of fish from lesser developed island areas where fish are abudant."

The first volume of the report, "Fishery Statistics of the Western Pacific," is a compilation of fishery statistics for American Samoa for 1982-1984; the Commonwealth of the Northern Mariana Islands, 1979-84, and Hawaii, 1979-84. The second volume will contain summaries for Guam and will be published in the summer of 1986. A third volume which will be published during the fall of 1986 will report landings for 1985 for all of the regions. According to Hamm, subsequent volumes will be annual updates and will be published as soon as possible after the data are processed following the close of the calendar year.

This series of reports is generated from a computerized data management and collection system for the western Pacific called WPACFIN, (Western Pacific Fishery Information Network)

which Hamm designed and implemented with the cooperation of participating island government fishery agencies and private industry.

NOAA, PRC Scientists Study El Niño Sources

Chinese and American scientists participating in an international climate research cruise aboard the Chinese research ship *Xiangyanghong #14* were honored in Honolulu in ceremonies sponsored by NOAA. the *Xiangyanghong #14*, which means "the sun rising red," was the first Chinese research ship to visit Hawaii. During the visit, NOAA Administrator Anthony J. Calio and American scientists and other officials conferred with Yan Hongmo, director general of the People's Republic of China State Oceanic Administration, and members of a visiting Chinese science delegation.

The *Xiangyanghong #14* and its Sino-American scientific party sailed from Honolulu in January to search for the sources of "El Niño," the mysterious Pacific Ocean current. The reseach is part of a 10-year international climate study organized by the World Meteorological Organization and the International Council of Scientific Unions. Called TOGA (Tropical Ocean/Global Atmospheric Program), the program is considered a landmark in U.S.-Chinese cooperation.

TOGA scientists are trying to predict future occurrences of the El Niño, which turns the world's weather topsy turvey every 2-7 years. Because devastating effects on fish were first noted by South American fishermen around Christmas time, the phenomenon was named El Niño, Spanish for "the child." The last El Niño occurred in 1982-83 and brought unprecedented death and damage to many. The incident disrupted fishing all along the Pacific coast of South America and caused immense storm damage along the entire west coast of North America.

For the first time in 75 years, French Polynesia was hit with a typhoon—and then was hit five more times in the next 5 months. Australia had its worst drought in 200 years. In New Zealand it was "the summer that never was." In Northwest Africa, the winter rains never came. The Ethiopian drought intensified and spread southward along the entire east African continent. In China, El Niño brought floods to southern regions and drought to the north.

Scientists from Duke University, Woods Hole Oceanographic Institution, Louisiana State University, and NOAA's Pacific Marine Environmental Laboratory, participated in the research. From Honolulu, the *Xiangyanghong #14* sailed for tropical waters west of the international date line to measure variations in heat transported by east-west currents along the equator. Scientists moored meters on the equator near the Gilbert Islands and measured subsurface currents and temperatures to help validate measurements made by satellite.

Meteorological measurements were made by the ship throughout the cruise in this sparsely monitored region of the Pacific Ocean. After a brief stop on Ponape in the Caroline Islands, the ship returned to its homeport of Guangzhou, China, in late February. Over the next 10 years, a number of countries, including France, Australia, Chile, and Peru, will work on the TOGA Program. In addition to research cruises, scientists will increase atmospheric measurements worldwide and develop numerical models and other methods to predict abnormal variations in weather and climate, and help lessen the often devastating effects they have on the world.

Histological Techniques for Marine Bivalves

The National Marine Fisheries Service Laboratory in Oxford, Md., announces the publication of a manual of "Histological Techniques for Marine Bivalve Mollusks." This manual describes and illustrates techniques used by the Oxford Laboratory in processing marine bivalve mollusks for histopathological examination. Anyone interested in this manual should contact the authors, Dorothy Howard and Ceil Smith, at the NMFS Oxford Laboratory, Oxford, MD 21654, regarding its availability as copies are very limited.

Kemp's Ridley Sea Turtles Released in Texas Waters

On 22 April and 6 May, about 1,550 tagged Kemp's ridley sea turtles, *Lepidochelys kempi*, were released by the NMFS Southeast Fisheries Center's Galveston Laboratory staff. About 560 turtles were released in the western portion of Copano Bay near Corpus Christi, Tex., and the other 990 turtles were released 6-8 n.mi. off North Padre and Mustang Islands, near Corpus Christi. These turtles represent the 1985 year class, the eighth year class of head-started turtles at the laboratory since 1978.

Kemp's ridley sea turtle is the most endangered species of sea turtles. Head starting is being tested as one of several conservation strategies for Kemp's ridley recovery. Kemp's ridley eggs are collected each year on the only known nesting beach in the world, a 20 km stretch of beach near the Mexican village of Rancho Nuevo, in the State of Tamaulipas, bordering the western portion of the Gulf of Mexico.

The eggs are placed in polystyrene foam boxes containing sand from the National Park Service's Padre Island National Seashore where they are incubated and hatched. The hatchlings are exposed to sand and surf at Padre Island to "imprint" them, in hopes that they will return to reproduce and lay eggs on Padre Island, thus establishing a second nesting colony in the United States. "Imprinted" hatchlings are reared at the NMFS Galveston Laboratory for 1 year or less; then the survivors are tagged and released in Texas waters near Corpus Christi, with the intent of reinforcing any imprinting they may have attained as hatchlings.

The head start project, now in its ninth year, has released 9,258 tagged Kemp's ridleys so far, and about 400 have been recovered, most from sites in the Gulf of Mexico, but others on the Atlantic coast of the U.S., and two as far away as France and Morocco. Though it is not known how long it takes for Kemp's ridleys to mature, estimates range from 6-13 years. Because the oldest of the head-started ridleys released into the wild are approaching 8

years of age, National Park Service biologists will be patrolling Padre Island this spring in search of nesters.

Cooperating in the project are Mexico's Institute Nacional de la Pesca, the U.S. Fish and Wildlife Service, National Park Service, National Marine Fisheries Service, and the Texas Parks and Wildlife Department. Other participants have included the Gladys Porter Zoo, U.S. Coast Guard, U.S. Navy, Florida Department of Natural Resources, Texas A&M University, University of Texas, and the Houston Zoological Gardens.

Public awareness and support for the project have been promoted by a nonprofit organization, HEART (Help Endangered Animals—Ridley Turtles), a special committee of the Piney Woods Wildlife Society, North Harris County College, Houston, Tex. Private sector contributions to HEART in support of the project have been made by EXXON Corporation[1], the Kempner Fund, and Pel-Tex Oil Company. For additional information contact: Charles W. Caillouet, Jr., Chief, Life Studies Division, NMFS, SEFC Galveston Laboratory, 4700 Avenue U, Galveston, TX 77550.

South Pacific Albacore Studied

Significant progress has been made in measuring oceanographic features thought to be important indicators of the availability of albacore, *Thunnus alalunga*, in the South Pacific, reports NMFS Honolulu Laboratory biologist Jerry A. Wetherall, head of a scientific group aboard the NOAA ship *Townsend Cromwell*. The *Cromwell* worked together earlier this year with a New Zealand research vessel to measure variation in temperature and salinity of ocean waters down to a depth of 1,000 m in an area east of New Zealand where albacore had been caught in previous exploratory fishing expeditions, according to Richard Shomura, NMFS Honolulu Laboratory Director.

Within their preferred temperature range, albacore often associate with the boundaries between different water masses, and thus are often found where temperature and salinity of the near-surface waters change abruptly. In addition to mapping temperature and salinity changes, the *Cromwell* and the New Zealand vessel sampled the surface waters by trolling artificial lures, but encountered few albacore during this part of the survey.

A second phase of the survey was conducted by the *Cromwell* several hundred miles further northeast in an area south of Tahiti where two U.S. commercial albacore trolling boats, the *Day Star* and the *Bald Eagle*, had encountered a significant concentration of albacore and were making good catches. The commercial boats were partly assisted by Federal Saltonstall-Kennedy funds granted to the Western Fishboat Owners Association by the Pacific Fishery Development Foundation. Additional support was provided by the American Fishermen's Research Foundation, a U.S. albacore industry group. The *Cromwell* completed a survey of temperature and salinity conditions in the region of good albacore fishing, and trolled throughout the area in cooperation with the fishing boats. Data collected during the survey will be studied for clues which may improve albacore fishing strategies and knowledge of albacore migration behavior.

In conjunction with the oceanographic surveys, Honolulu Laboratory biologists Victor A. Honda, Thomas K. Kazama, and Bert S. Kikkawa gathered data on albacore maturation, food habits, parasites, aging, and growth rate. Albacore were also tagged and released to provide information on their migration paths in the South Pacific. The commercial vessels were active collaborators in the research, tagging and releasing several hundred albacore and collecting measurements of sea surface temperature as they fished.

The *Cromwell*, under the command of David McConaghy, is assigned yeararound to work with the Honolulu Laboratory, a unit of the NMFS Southwest Fisheries Center. The *Cromwell* helps carry out the Laboratory's research programs on a wide range of marine resources around Hawaii, American Samoa, Guam, and the Northern Marianas inside the 200-mile federal fishery zone. These include such resources as spiny and slipper lobsters, bottom fish, deepwater shrimp, and seamount groundfish. It also provides logistical support to NMFS's research programs on marine mammals and endangered species, which focus on the Hawaiian monk seal and the green sea turtle.

The Honolulu Laboratory also has responsibility for most Federal research on tuna and billfish resources in the central and western Pacific, and for albacore research in the South Pacific. According to Shomura, the NMFS tuna proglram involves monitoring major fisheries in the regions of interest to the U.S., assessing yield potentials for tuna and billfish stocks, and conducting biological and economic research to provide a rational basis for management policy decisions.

The *Cromwell*'s 10-week research cruise in the South Pacific, which ended 16 March, was the first phase of a cooperative, international effort to expand the South Pacific fishery for albacore and to develop a better understanding of albacore biology, distribution, and abundance. Collaborating with the Honolulu Laboratory in the research are the SWFC La Jolla Laboratory in California, the South Pacific Commission, the Governments of France and New Zealand, and the U.S. albacore fishing industry. The scientific team on the *Cromwell* included NMFS biologists and cooperating scientists from New Zealand, New Caledonia, and Tonga.

En route to the South Pacific albacore survey area, the *Cromwell* charted bottom depth contours on key bottomfish grounds in American Samoa, under the direction of Honolulu Laboratory biologist Stephen Ralston. The charts will be used to assist local fishery development programs. On the return trip to Honolulu, the *Cromwell* visited Rarotonga, Cook Islands, where an "open house" was held aboard the vessel. The *Cromwell* also mapped bottom depths and temperature profiles under several fish aggregating devices (FAD's) used for tuna fishing near Rarotonga.

According to Shomura, the Honolulu

[1]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Laboratory's research program in the South Pacific is expected to continue next year. An international meeting will be held in Auckland, N.Z., in June to review this year's preliminary albacore research and set goals for additional surveys.

Lost, Stolen Fish Trap Responsibilities Noted

A court decision issued in 1985 by Administrative Law Judge Hugh Dolan, U.S. Department of Commerce, has established several responsibilities for trap owners fishing in the U.S. fishery conservation zone (FCZ), according to Jack Brawner, Director, NMFS Southeast Regional Office. Fishermen who meet their responsibilities will avoid penalties for lost or stolen traps that are found in portions of the FCZ closed to the use of traps. Trap owners, whether recreational or commercial, are responsible for:

1) Placing and marking their traps in such a manner as to facilitate relocation of the traps,
2) Making an honest and thorough effort to locate any missing traps, and
3) Reporting the loss or theft of traps to the appropriate authority.

To meet the last responsibility, southeastern U.S. trap owners should file a written report of traps missing from the FCZ in the Southeast Region (waters off North Carolina through Texas, the Virgin Islands, and Puerto Rico) with the Regional Director, National Marine Fisheries Service, 9450 Koger Blvd., St. Petersburg, Fla. The written report must contain the following information: Time and date of report, number of missing traps, color code and trap permit numbers, specific location traps were placed and lost, date the loss was discovered, and a description of how you discovered traps were missing and what steps you took to locate traps (including name, address, and phone number of any witnesses). Keep a copy of the written report for your records. (The court decision does not apply to state violations.)

Note: Federal penalties of up to $25,000 may be sought for illegal use of traps. The filing of a written report is the only method of satisfying an owner's responsibility for reporting loss or theft of traps. The failure to file a prompt written report will be considered as indicative that the traps were not lost or stolen.

Rehabilitated Monk Seals Are Released

The National Marine Fisheries Service (NMFS), with the assistance of the U.S. Coast Guard, released two young Hawaiian monk seals at Kure Atoll in the Northwestern Hawaiian Islands on Monday, 5 May, reports Richard S. Shomura, Director of the NMFS Southwest Fisheries Center's Honolulu Laboratory. "These two monk seals were collected at French Frigate Shoals during the summer of 1985 to keep them from starving to death in the wild," noted Shomura. The two seals weighed about 200 pounds each at release, following their "rehabilitation" at the Waikiki Aquarium and the NMFS Kewalo Research Facility.

According to William G. Gilmartin, Leader of the Marine Mammals and Endangered Species Program, which includes this monk seal work, three female monk seal pups were collected for the same reason in 1984 at French Frigate Shoals and were similarly rehabilitated and released at Kure in 1985. "These seals have adapted well to their new home and are regularly being seen on the beaches at Kure," Gilmartin said.

To make their reintroduction to the wild as easy as possible after their flight to Kure, courtesy of the Coast Guard, the yearling seals were placed into a large fenced enclosure which included sandy beach and water. The enclosure was stocked with live fish and lobster collected for them by NMFS biologists and off duty Coast Guard personnel. "We believe it is important to ensure that the seals will catch food for themselves before they are finally released, and our experience indicates that up to a few weeks in the enclosure is sufficient time to allow them to convert from a hand-fed diet of frozen fish to catching their own live prey," Gilmartin said.

Shomura said that the reason this relocation is being done is because "the Kure Atoll seal population has declined more than 80 percent over the last 25 years and it is hoped that adding a few new females each year will start a recovery there." Shomura added that "although the French Frigate Shoals population is the largest of all the breeding populations, it is experiencing the highest mortality rate in young seals."

Gilmartin believes that this may be because this population has grown to a point at which it is now food limited, but much more research will be necessary to fully understand why this mortality is occurring and what can be done about it. "If the population there is indeed food limited," Gilmartin said, "then returning the rehabilitated seals to French Frigate Shoals would only further stress that population. Moving these seals to Kure Atoll, where the population is much reduced, has the advantage of adding reproductive potential to that area."

WHO EATS FISH AND SHELLFISH?

The more people earn, the likelier they are to eat seafood away from home, and half of the time they choose shellfish. Those are just two characteristics of American seafood consumption patterns reported by Teh Hu, professor of economics at Pennsylvania State University. Hu's government-published survey also found that people living in cities eat less finfish away from home than people in the country, but they eat more shellfish; that people in mountain regions have increased their seafood consumption; that underutilized species—notably swordfish, dolphin, and squid—are popular away-from-home sales with middle-income and upper-income caucasians in cities in New England or the Pacific Coast region; and that black Americans eat more shark than caucasians do.

The complete report, which compares four major surveys on seafood consumption since 1969, is available for $19.95 postpaid from the National Technical Information Service, Order Desk, 5285 Port Royal Road, Springfield, VA 22161. Ask for Publication No. PB-86135043.

The South American Centolla Fishery

Introduction

Chilean and Argentine fishermen caught nearly 2,950 metric tons (t) of centolla, *Lithodes antarcticus* (Fig. 1) in 1984, about the same as in 1983 (Table 1). The species is also known as southern or South American king crab[1]. Most of that catch (almost 2,750 t) was taken by Chilean fishermen, although continued growth of the Chilean catch will be limited by the size of the resource.

While no definitive Chilean stock assessment estimates exist for the whole range of the fishery, most observers do not believe the resource will support significantly expanded fishing. The potential for increased centolla catches, however, may be greater off the coast of Argentina because of the country's broad Patagonian shelf which may provide excellent habitat for the crab. The Argentine Government, however, has not yet assessed the centolla stock on that shelf.

Argintine stock assessments conducted in the Beagle Channel where the current fishery is based suggest a very limited stock. Developments in the centolla fishery are of interest to the United States because some observers view centolla as a possible competitor for Alaskan king crab, *Paralithodes camtschatica*. U.S. imports of Chilean crab (primarily centolla) increased significantly from 190 t in 1977 to 550 t in 1984.

Species

The South American centolla fishery is conducted primarily for *L. antarcticus*. Smaller catches are also taken of a related species, centollon, *Paralomis granulosa* (Table 2), also called false southern king crab. Another related species, centolla espinuda, *L. murrayi*, also called Murray king crab, reportedly occurs in the southeastern Pacific, but no resource estimates have yet been compiled on it.

The centolla is closely related to the Alaskan golden king crab, *L. aequispina*, and its outward appearance is very similar except for size and coloration. Sexually mature male centolla average about 10 cm (shell length), and weigh about 0.7 kg, which is somewhat smaller than Alaskan king crab whose average weight is about 2.5 kg. The average size, however, varies with the grounds. In Chile, the average weight in the major commercial grounds located in the south is about 1.5-1.8 kg. No data are available on weight variation along the Argentine coast. In coloration, the centolla is similar to its more distant cousin the Alaskan red king crab, *Paralithodes camtschatica*, but the shade varies by depth, age, and stage of the spawning cycle. The bright red color of centolla and Alaskan red king crab gives the animals a special appeal in the marketplace. Centolla differs from the Alaskan red king crab, however, in that its body and legs are covered with sharp spines up to 1 cm long.

Table 1.—South American centolla catch, 1975-84, in metric tons.

Year	Chile	Argentina	Uruguay	Total
1970	400	200		600
1971	400			400
1972	400			400
1973	400			400
1974	511			511
1975	609	362	3	974
1976	1,028	279	2	1,309
1977	1,306	322	10	1,638
1978	1,908	370	4	2,282
1979	2,265	62	21	2,348
1980	1,351	77	5	1,433
1981	1,280	174	8	1,462
1982	1,473	203	1	1,677
1983	2,755	179	2	2,936
1984	2,746	200	NA	2,946

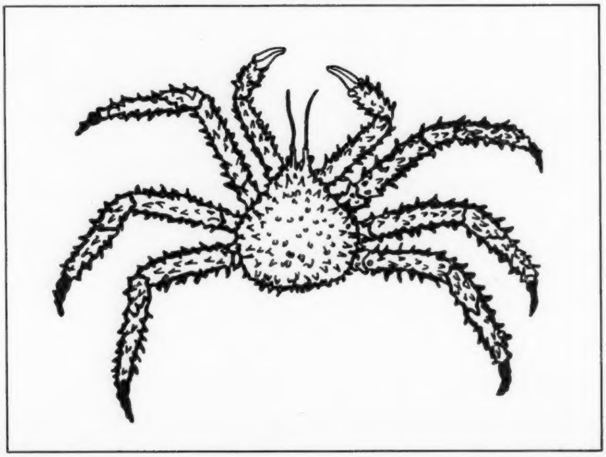
Source: FAO "Yearbook of Fishery Statistics" (1970-83 data); Servicio Nacional de Pesca, "Anuario Estadistico Pesquero" (1984 Chilean data); Instituto Nacional de Investigacion y Desarrollo Pesquero, unpubl. (1984 Argentine data).

Table 2.—Chile's centollon catch, 1978-84, in metric tons.

Year	Catch	Year	Catch
1978	637	1982	309
1979	952	1983	831
1980	429	1984	851
1981	310		

Source: Servicio Nacional de Pesca, "Anuario Estadistico de Pesca," 1978-84.

Figure 1.—South American centolla.



[1]The U.S. Food and Drug Administration has ruled that centolla cannot be labeled as "king crab" in the United States.

Habitat

The centolla is found along both the Pacific and Atlantic coasts of southern South America (Fig. 2). The crab primarily inhabits shallow water, usually in areas extending from the intertidal zone to depths of 150-200 m, although in some areas off northern Chile specimens have been found as deep as 600 m. The primary determining factor appears to be water temperature which is why the crab occurs in deeper water at the more northerly latitudes. The crab is found in areas with both rocky and sandy bottoms, but restricts itself primarily to the former during the molting period when it is most vulnerable to predators and tends to remain well hidden in the rocks and crevices.

Life History

Female centolla move into shallow water to molt and spawn during the southern hemisphere's spring and early summer seasons (December and January). Chilean tagging studies in the straits of Magellan and Argentine studies in the Beagle Channel have demonstrated that the crabs make no significant lateral migrations, but that they do move vertically in the water column, primarily for reproductive purposes. After mating they return to deeper water. The females carry the fertilized eggs for about 280-300 days before the larvae hatch the following spring (mid-September to early November). Young females produce about 5,000 eggs annually, while older females can produce 30,000 or more eggs. Females have been observed carrying from 2,000 to 60,000 eggs. Larval development comprises three stages of zoea and one of megalopa. The planctonic/zoeal life cycle lasts less than a month, with the actual time depending primarily on water temperature.

Male centolla molt later than the females, usually in March or April. The crabs move into shallow waters to molt and, because they are vulnerable to predators while their shells regenerate, they become less active and rarely venture from their hiding places among the rocks. As a result, catches are usually low during this period. Immature males usually molt twice a year, but this is reduced to a yearly molt long before the males reach legal size. Large males of 15 cm or more may go up to 2 years without molting. Centolla grow slowly. Studies conducted by the Argentine Instituto Nacional de Investigacion y Desarrollo Pesquero (INIDEP) determined that by the time the crab reaches a size large enough to be vulnerable to the traps, the growth rate of the carapace was an average of 9.3 mm per molt for males and 4.2 mm for females.

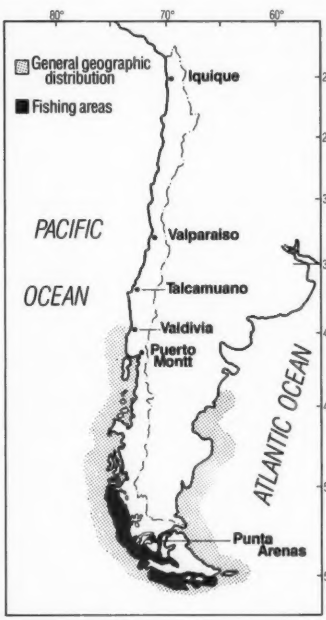


Figure 2.—Centolla distribution.

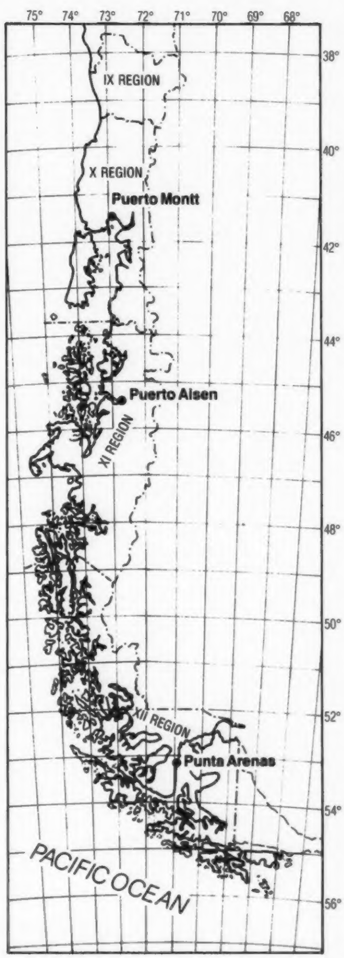


Figure 3.—Chile's southern administrative regions (IX-XII).

Fishing Grounds

Chile

Centolla is found from Cape Horn (lat. 55°5′S) north to Valdivia (lat. 38°48′S), although it has occasionally been observed as far north as Talcahuano. The primary Chilean fishery is located off the extreme southern coast from Canal Trinidad/Isla Wellington (lat. 50°S) to Cape Horn (lat. 55°40′S), a range of about 650 km, which covers an area of about 132,000 km (Fig. 2). The greatest known resource concentration is off southern Chile in the Straits of Magellan and surrounding area[2] and it is there where most of the commercial catch is taken. Until 1974, the fishery was limited almost exclusively to the Straits of Magellan, but has since been extended to several new grounds in Region XII.

Chile's southern administrative regions are shown in Figure 3. A much smaller and less productive fishery is centered around Puerto Montt in Region

[2]The grounds are located in Magallanes, Chile's XII Region, where almost all of the catch is taken.

X, about 2,000 km to the north (Table 3). Between those two areas are hundreds of kilometers of rugged coastline. There are no roads linking southern Chile with the more populated central area of the country. The south is isolated by 400 miles of mountains, glaciers, and deeply indented coastline. Chilean biologists believe that crabs occur along the entire coast south of Puerto Montt, but the size of the resource does not warrant the investment necessary to conduct fishing operations in the central area.

Argentina

There is a small traditional centolla fishery located on the Argentine side of the Beagle Channel on the southern edge of Tierra del Fuego. The growth potential of this fishery is minimal because of the limited stocks there. In August 1979 the Argentine Government imposed an 18-month ban on the taking of centolla in the Beagle and Moat Channels to allow stocks to recover. The ban was lifted in early 1981 but activity in the region was still strictly regulated and limited to artisanal fishermen. No centolla fishing is currently conducted on Argentina's broad Patagonian shelf, although some observers suggest that such an enterprise might be possible.

Table 3.—Chile's centolla catch by administrative region, 1982-84, in metric tons.

Region	Catch (t) 1982	1983	1984
I-IX			
X	30	21	47
XI	2	46	17
XII	1,441	2,688	2,682
Total	1,473	2,755	2,746

Source: Servicio Nacional de Pesca. "Anuario Estadistico de Pesca," 1982-84.

Table 4.—Chile's centolla catch per unit of effort in Region XII during the main fishing seasons (July to January) 1979-84[1].

Area of Region XII	CPUE (crabs/trap) 1979-1980	1980-1981	1981-1982	1982-1983	1983-1984
1	0.62	0.86	0.83	NA[2]	NA
2	0.55	0.48	0.60	0.62	0.82
3	0.55	NA	NA	0.99	1.73
4[3]	0.56	0.69	0.80	NA	1.10
4A	NA	NA	1.06	1.02	NA
5[3]	0.90	0.89	1.23	1.07	1.34
6[3]	1.36	2.15	1.54	1.68	1.91
7[3]	1.13	NA	1.07	0.97	1.17
8	0.98	1.34	0.81	1.01	0.96
9[3]	NA	1.39	1.33	1.19	1.23
10	NA	NA	NA	1.12	1.16

[1]Source: Beatriz Hernandez, "Southern King Crab (*Lithodes antarcticus*) of the Magellan Region, Chile," Instituto de Fomento Pesquero, 1985.
[2]NA = Not available.
[3]Primary fishing areas.

Stocks

Chile

No comprehensive study has been conducted to assess the centolla stocks. Most observers, however, believe that Chilean stocks of centolla are probably not sufficient to support greatly expanded commercial operations. The resource is thinly distributed in most areas and past attempts to establish such operations have resulted in depletion of the stocks in the target areas. One factor limiting the stocks is the extent of the habitat along the Chilean coast. Unlike the broad continental shelf which supports the Alaska's larger king crab fishery, the western coast of South America plunges steeply into the Pacific, thus limiting the potential habitat to a narrow band along the continental slope. Available data suggests that, except in a few specific areas, the resource is not yet being overfished. Available catch per unit of effort data, for example, has shown a slight increase in catch rates during recent years (Table 4).

Argentina

Argentine centolla stocks have not been fully assessed either. INIDEP has conducted some research in the Beagle Channel where the small Argentine fishery is currently based, much with the cooperation of the three Argentine companies which process centolla. Based on their research, INIDEP believes that the Beagle stock could yield about 136,000 crabs per year or, roughly, perhaps 315 t. INIDEP officials caution, however, that because of fluctuations in effort due to catch limitations during recent years, historical data is not sufficient to base a reliable maximum sustainable yield estimate.

Argentine stocks could eventually be proven larger, although no studies have yet substantiated this hypothesis. The Patagonian continental shelf off Argentina extends for hundreds of kilometers into the Atlantic, beyond the Falkland Islands. That broad shelf would appear to offer an excellent habitat for centolla and other crabs. Test fishing conducted so far, however, has found no large, commercially exploitable stocks. The Argentine Government has not made centolla a priority research subject, but plans do exist for more frequent research. The only indications of the size of the resource on the Patagonian shelf off Argentina comes from trawl fishermen who have reported incidental catches of centolla while fishing for hake and other demersal species.

Vessels

Centolla fishermen use several types of vessels ranging from small nonmotorized wooden vessels less than 7 m long to modern steel-hulled vessels of over 20 m. About 50 percent run 8-17 m. Most of the fishermen use wooden vessels that are built locally and average about 10 m in length. Fishermen using the larger steel-hulled vessels generally report the best catches. The smaller boats (<8 m) are not capable of deploying traps efficiently and some are allegedly involved in the illegal tangle net fishery.

One recently formed Chilean company has requested and received funds from the Chilean Development Corporation (CORFO) and the Inter-American Development Bank (IDB) for the construction of 45 vessels especially designed for the capture of centolla and other crustaceans. The vessels will be steel-hulled but smaller than those steel-hulled commercial vessels currently operating in the fishery. The 14 m vessels will be small enough to maneuver among the narrow fjords and channels of southern Chile, but also sturdy enough to operate in the open ocean. Each vessel will carry between 300 and 400 traps which will be raised and lowered with the aid of hydraulic winches. In addition to the 45 capture vessels, the company also has contracted to purchase 10 vessels to transport the catch from the grounds to the processing plant.

Fishing Methods

For many years tangle nets were the primary means of catching centolla. This method proved counterproductive, however, because the nets were not selective in their catch and centolla of all sizes became entangled. Many juvenile crabs were thus lost to the fishery because they died before they could be freed from the nets or were injured so badly that they had little chance of surviving. Argentina banned the use of nets to capture centolla in 1975 and Chile issued similar regulations in 1980. Thus, the crabs can be legally harvested with traps only. The traps are generally conical with a base diameter of 1.6 m and a height of about 0.6 m. They are deployed in sets of 10-20 traps and baited with fish, although some other baits such as marine mammals and birds are allegedly used illegally at times. Most of the vessels are equipped with mechanical winches to raise the traps.

The success of the fishermen depends on many factors, most importantly their knowledge and experience. The areas of highest concentration of the resource vary during the year according to the reproductive cycle, water temperature, and the strength and direction of currents. A knowledge of the area and the habits of the centolla permit the fishermen to place their traps in the best places for harvest. The steep underwater terrain in many places is also a factor which must be considered. If the traps are not set carefully on a relatively level site, many of them will land upside-down or on their sides, resulting in little or no catch. The traps are usually left in place for 2 days and then retrieved. If the catch is good, the traps are re-baited and set in the same place; if the catch is small, they are relocated. Fishermen consider three or four crabs in a pot after 2 days to be a good catch.

Regulations

Chile

Chilean officials first set fishing regulations for centolla in 1934, although these apparently were not based on any scientific investigation of the species' life cycle. Since those early regulations, the species has been more carefully studied. The Servicio Nacional de Pesca (SERNAP) has conducted a research program since 1979. The primary management regime is based on a prohibition on the take of juvenile crabs (<12 cm carapace[3]) and on all female crabs. Originally only the harvesting of berried females was prohibited, but because females carry eggs for a substantial part of the year and because the ban on taking berried females was being constantly violated, the capture, transportation, and marketing of all females was prohibited in 1973.

The only other major fishing restriction is that the crabs can only be caught by traps. Since 1980, the use of tangle nets has been prohibited. Chilean officials, however, are concerned about the enforcement of these regulations, especially in the more remote areas. Officials believe, for example, that a large number of tangle nets are still illegally employed. Other restrictions are occasionally enforced such as area closures. Fishing in the Porvenir area, for example, was closed from October 1981 to October 1985 because of the heavy fishing effort there since the beginning of the fishery.

The Chilean Government is currently preparing a new management plan for centolla. The major objectives of the proposed plan are to: 1) Reduce the risk of overfishing, 2) better utilize the resource, and 3) establish a permanent data base. The proposed plan would maintain the current regulations concerning minimum sizes, gear restrictions, and prohibition on taking females. The plan includes an additional regulation establishing a closed season from 1 December to 15 January to protect the crabs during the mating season.

The cost of conducting research precludes a regular program of stock evaluation and, as a result, the proposed plan does not entail the establishment of an overall quota based on an estimation of a maximum sustainable yield. The plan does make provision, however, for temporary area closures if officials believe that stocks are being depleted in small areas. Officials are particularly concerned, for example, about the status of stocks in some of the new fishing areas recently opened and for which little data on catch, size frequency, and effort are available.

The Chilean centolla fishery is highly seasonal. Fishing effort in the southern fishery tends to be at low levels during February to March, but begins to increase in June and is at its peak during November and December (Table 5). Full-scale commercial crabbing begins in August or September and most of the catch is landed between August and February. During 1984, for example, about 80 percent of the catch was landed in those months. In recent years the fishermen have been fishing more during the off season (February to May). While still low, catches during this period have been increasing (Table 5). Many fishermen, however, report that the condition of the crabs, especially during April is inferior and meat yields are lower.

Table 5.—Chile's centolla catch in the major fishing area of Magallanes (Region XII) 1982-84[1].

	Catch (t)		
Month	1982	1983	1984
January	208	278	244
February	58	121	202
March	26	67	135
April	23	53	54
May	33	97	107
June	48	123	113
July	62	162	157
August	87	208	255
September	113	287	369
October	145	389	328
November	289	488	402
December	349	415	316
Total	1,441	2,688	2,682

[1]Source: SERNAP, "Anuario Estadistico de Pesca," 1982-84.

Argentina

The Argentine Government changed the legal season and other regulations repeatedly throughout the 1970's. The continued changes reportedly confused fishermen, many of whom allegedly ignored the regulations, as well as enforcement agents who were hesitant to take action against violators. The result was that by 1979 the traditional fishery in the Beagle Channel showed signs of overfishing and the area was closed

[3]Measured from the orbit of the eye to the extreme lower half of the thorax.

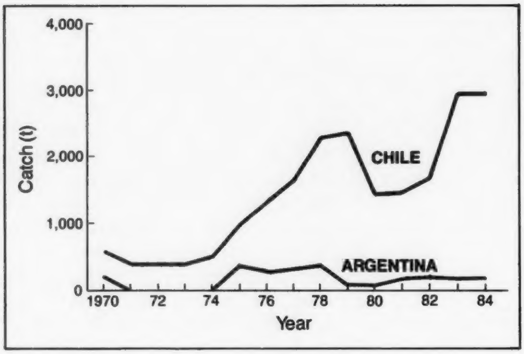


Figure 4.—The South American centolla catch, 1970-84, in metric tons.

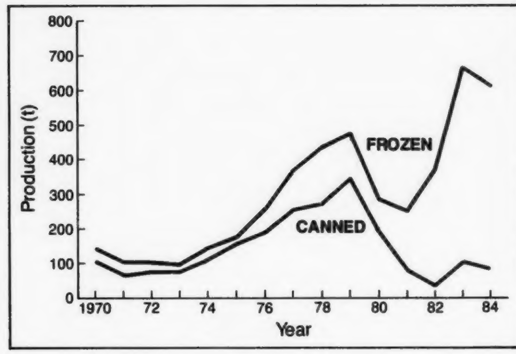


Figure 5.—Chilean centolla processing, 1970-84.

from August 1979 to January 1981. The Government passed a new resolution in 1981, based on a 2-year study by INIDEP, which prohibited the taking of centolla in the Beagle and Moat Channels from 1 October to 31 December each year. The resolution also limited the number of traps allowed in the area at any one time to 1,000. Argentina, like Chile, also totally prohibited the taking of females and set 12 cm as the minimum legal size for males.

Catch

Chile

Chilean centolla catches are at near record-high levels. Chilean fishermen harvested about 2,750 t of centolla in 1984, about the same quantity harvested in 1983 (Fig. 4), but substantially more than in 1982 and earlier years. The Chilean catch began expanding in 1974, reaching a peak of 2,300 t (the previous record) in 1979. Catches increased as fishermen intensified fishing efforts and expanded into new grounds. Initially, the fishery had been conducted almost exclusively in the Straits of Magellan. Beginning in 1974, fishermen also began to deploy traps in several new areas: Beagle Channel, 1974; Cape Horn Archipelago, 1976; Ano Nuevo Inlet, 1979; Nelson Strait, 1980; and the Trinidad Channel, 1982.

Even though fishermen expanded fishing to new grounds, the catch dropped sharply in 1980 (Table 1). Chilean sources report that the catch declines from 1980 to 1982 are the result of a combination of factors, primarily the fishermen reducing their effort as listed below[4], as demand and prices declined.

Chile's centolla fishing effort, 1979-1984.

Season	Thousand traps
1979-1980	1,444
1980-1981	649
1981-1982	734
1982-1983	824
1983-1984	1,172

In 1980 the catch was primarily marketed canned in Europe and the Chilean fishermen reduced their effort when the European market collapsed in 1980. The opening of a new market for frozen product in the United States has enabled fishermen to resume extensive fishing and set new records since 1982.

Argentina

The Argentine catch historically has been low compared with Chile's. In 1978, Argentina landed a record 370 t, but the catch has subsequently declined. The 1984 Argentine catch was 200 t, a 10 percent increase over the 180 t taken in 1983. Much of the Argentine total is actually caught by Chilean fishermen working aboard Argentine vessels.

Processing

The Chilean commercial centolla fishery began in 1928. Initially, the processing plants operated only from October to December and were closed the rest of the year. The industry developed slowly until the 1950's. Most of the catch was initially canned and marketed domestically. During the 1960's, freezing plants were opened. Today most of the plants operate all year. The major processing center is located at Punta Arenas in the Strait of Magellan. A smaller processing center is also located at Puerto Chacabuco for the small northern fishery. Processors report a meat recovery rate of about 22 percent of live weight (about the same as Alaskan king crab). Most of the meat is packed by hand to take advantage of the low labor rates. The meat is either frozen or packed in cans that vary from 110 to 240 g net weight. The frozen product is available as mixed meat, white meat, legs, claws, clawmeat, and whole.

There have been sharp fluctuations in processing patterns. Almost all of the catch was canned until 1976 (Fig. 5). Frozen production exceeded 100 t for the first time in 1977. After a collapse

[4]Source: Beatriz Hernandez, "Southern King Crab, *Lithodes antarcticus*, of the Magellan Region, Chile," Instituto de Fomento Pesquero, 1985.

in the traditional European market for canned Chilean centolla in 1980, Chilean companies turned to the U.S. market and as a result increased production of frozen centolla. Frozen production exceeded canned production for the first time in 1981. In 1984, frozen production totaled almost 530 t, about 90 percent of total Chilean centolla production.

Quality standards in Chile can vary widely. Chilean seafood companies have had more difficulty meeting U.S. standards than companies of any other Latin American country. However, most of the major companies packing centolla are now producing a good quality product and today very little centolla is detained by U.S. customs authorities. Some U.S. importers have helped the Chilean companies to improve their quality standards. In recent years, however, Chilean officials have expressed concern over the proliferation of small new companies created to process the increasing catch of centolla. Officials are concerned that the processing facilities of these companies are often relatively primitive and that quality standards are virtually nonexistent. Most buyers overcome this problem by inspecting both the product and the processing plant before making purchases.

Several major companies process and market centolla in Chile, and only a few operate their own fishing vessels. Instead, most have large vessels that travel throughout the major fishing areas and purchase the catch of artisanal fishermen who keep their catch alive in holding cages until they can be sold. The largest company dedicated to the capture and processing of centolla appears to be a newly formed enterprise, Pesquera Esmeralda[5], which was founded in 1984. The company claims that its processing plant, near Punta Arenas, is the most modern in South America. The plant includes a complete factory transported from Alaska for the processing of centolla, as well as other crabs. As mentioned, the company has received funds from CORFU and the IDB to purchase 55 vessels to supply its processing operations.

The Argentine centolla fishery is strictly artisanal, and virtually no information is available on its centolla processing facilities. Three companies located in Ushuaia process most of the catch, but a few additional companies involved in the processing of other seafood products also process a limited amount of centolla.

Exports

Chile

The Chilean centolla industry depends primarily on the export market; only about 25 percent of the catch is marketed domestically. Exports in 1984 totaled nearly 530 t (product weight) valued at $7.4 million (Table 6). Shipments declined in 1984, probably because of a corresponding catch decline. The industry has still not surpassed the record export level of 830 t reported in 1979. Most exports are now shipped frozen. In 1984, frozen shipments totaled 443 t, compared with only 84 t of canned product.

The markets and presentation of Chilean centolla have undergone dramatic changes since 1980. European countries (especially France) were the traditional market for centolla, purchasing more than half of the centolla exported from Chile between 1972 and 1981, mostly canned product.

However, the European market for

Table 6.—Chilean centolla exports by value (1970-84) and volume (1978-84).

	Value ($US million)			Quantity (t)			
Year	Frozen	Canned	Total[1]	Fresh	Frozen	Canned	Total[1]
1970		$0.1					
1971		0.1					
1972		Negl.					
1973		Negl.					
1974		0.2					
1975		0.6					
1976		1.5[2]					
1977		3.0[2]					
1978		3.6[2]				206[2]	NA
1979	$0.8	3.3			73	757	830
1980					42	240	282
1981				9	62	149	220
1982	4.8	1.4	$6.1		361	137	498
1983	7.9	1.4	9.3		554	81	635
1984	5.9	1.4	7.4		443	84	527

[1]Totals may not agree due to rounding.
[2]Includes some other crabs.
Source: SERNAP, "Anuario Estadistico de Pesca," 1978-84.

Table 7.—Chile's frozen and canned centolla exports, in metric tons, by country of destination, 1981-84[1].

	1981			1982			1983			1984		
Country	Frozen	Canned	Total	Frozen	Canned	Total	Frozen	Canned	Total	Frozen	Canned	Total
U.S.	38.3		38.3	239.8	11.4	251.2	305.0	NA	NA	290.6	19.4	310.0
France	2.5	80.4	82.9		82.5	82.5	32.5	NA	NA	71.3	37.1	108.4
U.K.		24.8	24.8									
Japan				34.1	10.7	44.8	67.7		67.7	13.7	0.2	13.9
Italy		22.1	22.1	14.3	24.2	38.5				7.0	8.9	15.9
Netherlands				25.2		25.2				42.0	10.2	52.2
Germany								NA	NA	12.3	5.1	17.4
Argentina	12.7	0.5	13.2									
Mexico		10.9	10.9									
Belgium	4.0	1.6	5.6	41.1	2.8	43.9	36.6	NA	NA	23.8	9.7	33.5
Brazil		5.2	5.2									
Other	4.4	3.7	8.1	6.9	4.9	11.8	4.6	NA	NA	16.2	2.4	18.6
Total	61.8	149.1	211.1	361.4	136.6	497.9	554.4	81.0	635.4	476.9	92.9	569.9

[1]Source: PROCHILE, unpublished statistics, and Servicio Nacional de Pesca, "Anuario Estadistico de Pesca," 1983 (1983 canned data). Totals may not agree due to rounding, and discrepancies with U.S. and other Chilean trade statistics (Table 6) are unexplained. NA = Not available.

[5]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

canned centolla collapsed in 1980. Large inventories of unsold centolla developed and Chilean companies were forced to seek new markets. Exporters reported good prospects in the United States. Sales increased sixfold in only 1 year, from less than 40 t in 1981 to over 250 t in 1982 (Tables 7 and 8). The United States is now Chile's most important customer for centolla. Purchases totaled 310 t valued at over $4 million in 1984, more than half of Chile's total centolla exports of nearly 570 tons (Fig. 6)[6]. Most of the centolla marketed in the United States is frozen. The European market, especially France, continues to be important, but much less so than before 1980. Demand in Europe has also shifted toward frozen centolla, and in 1984 all important European importers (except Italy) were ordering more frozen than canned centolla. The marketing of centolla in the United States may be affected by the U.S. Food and Drug Administration's decision not to allow centolla to be labeled as king crab, having decided that the term applies only the genus *Paralithodes* (Alaskan red king crab) and not *Lithodes* (centolla and golden king crab). A major U.S. seafood company has filed a petition with the FDA to change the ruling.

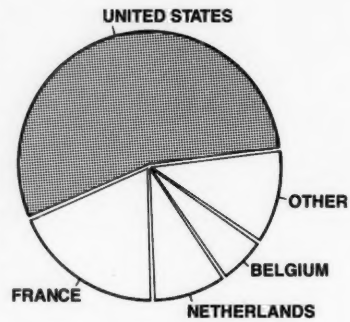


Figure 6.—Chile's centolla exports (total = 570 t) by country of destination, 1984.

Table 8.—U.S. crab imports[1] from Chile, 1977-84.

	Quantity (t)		
Year	Frozen	Canned	Total
1977	190.4		190.4
1978	170.2	10.3	180.5
1979	173.6	0.5	174.1
1980	24.4		24.4
1981	53.4		53.4
1982	176.2	11.3	187.5
1983	415.4	3.9	419.3
1984	532.9	16.7	549.6

[1]Estimated at about 70-75 percent centolla. Discrepancy with other tables is unexplained. Source: U.S. Department of Commerce.

Argentina

As stated, most of the production from Argentina's traditional centolla fishery is consumed locally; very little is exported. U.S. imports of all crab products (including centolla) from Argentina in 1984 was less than 4 tons. (Source: IFR-85/71).

[6]Available Chilean export data (Table 7) does not agree with U.S. import data in Table 8. The reason for this discrepancy is unknown, but could relate to various factors such as the time difference between shipment and receipt, losses in transit, and detentions. The problem is further complicated because U.S. import statistics do not list centolla separately, but include it in a larger crab and crab meat category. Observers believe that about 70-75 percent of U.S. Chilean crab imports is centolla.

Brazilian Fisheries, 1984-85

The Brazilian fishing industry is a relatively small sector of the national economy, representing only about 0.2 percent of the gross domestic product. Brazil exported a record $180 million worth of fishery products (mostly shrimp and lobster) in 1984, a 30 percent increase over 1983 shipments, but still less than 1 percent of the country's total exports. The Brazilian fisheries catch has grown steadily in recent years, reaching nearly 1.0 million metric tons in 1984, about 85 percent of which was taken in marine waters.

About 3.3 million people out of Brazil's population of 130 million depend on fisheries. Labor-intensive artisanal fisheries still account for half of the Brazilian fisheries catch. There are about 0.4 million artisanal fishermen in Brazil who still employ primitive fishing methods and gear. Domestic consumption of fishery products is also low, about 7.2 kg per capita in 1984, less than half of the world average of about 16.0 kg. Business opportunities for U.S. companies are limited, primarily because of restrictive Brazilian import regulations. Some opportunities do exist, however, for certain types of vessels, specialized equipment, and research devices. Other opportunities exist for U.S. companies leasing vessels and entering into joint ventures with Brazilian fishing companies.

The U.S. Embassy in Brasilia has prepared a 40-page report reviewing 1984-85 fishery developments. The report surveys important species (catfish, cod, shrimp), foreign trade, the closure of the whaling industry, fisheries management, development plans, export incentives, and other current developments. The report includes detailed statistical tables with catch, processing, and export data. U.S. companies can obtain a copy for $9.95 (personal checks or money orders) by ordering report PB-86-152469/GBA from NTIS, Springfield, VA 22161 and adding a $3.00 processing fee for each order. (Source: IFR-86/12 NTIS.)

Note: Unless otherwise credited, material in this section is from either the Foreign Fishery Information Releases (FFIR) compiled by Sunee C. Sonu, Foreign Reporting Branch, Fishery Development Division, Southwest Region, National Marine Fisheries Service, NOAA, Terminal Island, CA 90731, or the International Fishery Releases (IFR), Language Services Biweekly (LSB) reports, or Language Services News Briefs (LSNB) produced by the Office of International Fisheries Affairs, National Marine Fisheries Service, NOAA, Washington, DC 20235.

The Chilean Krill Fishery and Its Development

Introduction

Chile is one of five countries which has developed a commercial krill fishery. The Chilean Government believes that the country's small krill fishery could become an important part of the fishing industry in the next 10 years and is projecting export earning of $50-70 million by 1995.

IFOP, the Chilean Instituto de Fomento Pesquero (a government fisheries development corporation), first began to research the possibility of fishing Antarctic krill in 1974. Since then, two Japanese companies have established subsidiaries in Chile which have begun to catch and export krill. The 1983 catch totaled only about 5,000 metric tons (t), but Chilean officials believe that catches could be greatly increased and that krill could eventually become a major Chilean fishery. While the resource to support such a fishery does exist, a market for large quantities of krill products has not yet been developed.

Species

Six species of krill are found in the Antarctic: *Euphasia crystallorophias*, *E. frigida*, *E. superba*, *E. triacantha*, *E. vallentini*, and *Thionessa macrura*. *E. superba*, the principal species (Fig. 1), has been the subject of extensive scientific study in recent years because of the vast biomass that has been estimated by various researchers. Krill is widely recognized as the world's most abundant potential marine food source. Most published estimates of krill populations suggest a standing stock of 120-200 million t, with about 150 million t being the figure most commonly used.

Various authors provide estimates as high as 800 million t and one Soviet scientist (Moiseev, 1970) estimated 5,000-7,500 million t. Another Soviet scientist (Lyubimova, 1973), 3 years later estimated krill stocks at about 800 million tons. More recently some researchers have calculated a standing stock far below the commonly accepted 120-200 million t estimate. The validity of these lower estimates, however, has been questioned and they have not yet been published.

However, a stock of 120-200 million t could probably support annual catches of at least 40-50 million t, which could substantially increase the total world fisheries catch. The world catch of all species, for example, was only about 83 million tons in 1984. These potential krill catch figures are based on primary productivity estimates and thus only rough estimates of the potential yield from the fishery. While potential harvests cannot be forecast with any precision, the available estimates do suggest the possibility of substantially increasing the world's fisheries production. Chilean officials report that a large proportion of the Antarctic krill biomass tends to occur in the area of the Antarctic claimed by Chile, long. 53°-90°W (Fig. 2).

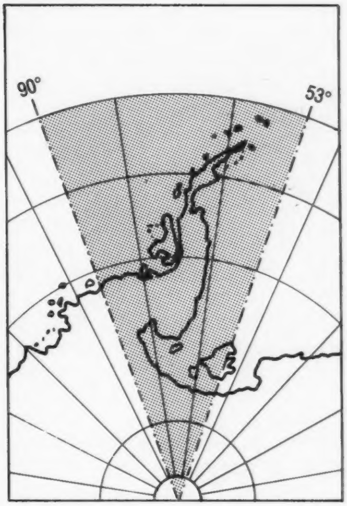


Figure 2.—Chilean Antarctic claim.

Antarctic krill measures about 4-5 cm in length and weighs about 1.0-1.2 g. Researchers have found that krill schools are very dense, up to 12 kg/m^3, and sometimes cover vast areas in dense swarms. Dense krill schools often congregate in the upper 100 m of the water column, especially near the surface. Daily vertical movements have also been observed, probably associated with feeding patterns. One of the key unanswered questions about krill is how long it lives. Some researchers believe that *E. superba* may reach sexual maturity at about 2 years and live a total

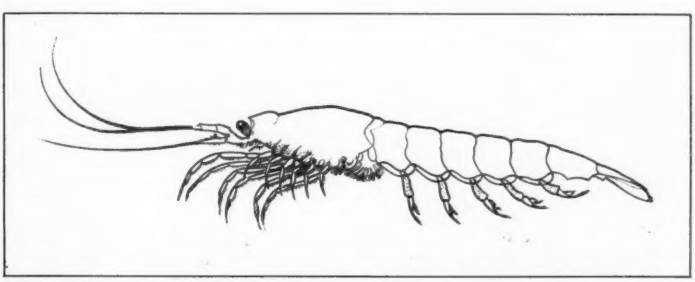


Figure 1.—The Antarctic krill, *E. superba*.

This news article, IFR-86/10, was written by Dennis Weidner, Foreign Affairs Officer, NMFS Office of International Fisheries, Washington, DC 20235.

of 4-6 years, although some estimates suggest life spans as long as 8 years[1].

Krill is found at depths ranging from 10 to 250 m. It is usually caught with midwater trawls with small mesh. Fishing is very difficult, however, because of the distance from important population centers and the severe climatic conditions. Handling the krill is also difficult because krill is very perishable. It has highly active digestive enzymes which will rapidly break down the flesh unless the catch is processed within 3-4 hours of capture. Even at cold Antarctic temperatures, fishermen have to be careful not to allow the krill to pile up over 0.3 m or heat will build up and spoil the krill in a matter of only a few minutes. Krill used for inedible products such as meal can be held for longer periods, but even that krill should be processed within 10-12 hours. It is therefore critical to develop procedures to quickly process the catch. This can prove extremely difficult as catch rates can be extraordinarily high, as much as 8 t in 5 minutes. Average catch rates are about 70 t per day.

Table 1.—Chile's krill research expeditions, 1975-85.

Agency	Vessel	Captain	Chief scientist	Dates
IFOP	*Valparaiso*	Osvaldo Gonzalez	Oscar Guzman	January-February 1975
IFOP	*Arosa Septimo*	Constantino Fiusa	Oscar Guzman	May-June 1976
IFOP	*Arosa Septimo*	Constantino Fiusa	Oscar Guzman	September-October 1976
INACH[1]	*Itzumi*	Aldo Pedrini	Oscar Guzman	January-February 1981
INACH[2]	*Capitan Alazar*	Manuel Lagunas	Patricio Eberhard	January-February 1984
INACH[3]	*Capitan Alazar*	Manuel Lagunas	Patricio Eberhard	January-February 1985

[1]Conducted as part of FIBEX; INACH = Instituto Antartico Chileno.
[2]Conducted as part of SIBEX I.
[3]Conducted as part of SIBEX II.

Research

Krill has been the object of scientific study for more than half a century. The two major fishing countries, the Soviet Union and Japan, have each spent over $200 million studying krill. Serious information gaps, however, still exist. The most significant gaps include: The relationship between currents, surface rings, and krill distribution; the biology of all krill species; feeding habits; spawning areas; life history; predation; and the role of krill detritus in the Antarctic ecosystem.

CORFO, the Chilean Corporacion de Fomento de la Produccion (Corporation to Promote Production), through its fisheries subsidiary, IFOP, conducted a krill research project (Programa Krill) from 1974 to 1976 which included Antarctic fishing expeditions. The first Chilean expedition in 1975 deployed the research vessel *Valparaiso* and landed 60 t of krill. IFOP made two more cruises in 1976 using the *Arosa Septimo* (Table 1). Peeling machinery was tested on the ship and ashore.

The krill taken during these cruises was used for extensive studies by IFOP and the Universidad Catolica de Valparaiso which developed various edible products. Those products developed by IFOP included breaded products, empanadas, and krill fingers, hamburgers, croquettes, sausages, minces, and pastes. Some of these products were subsequently test-marketed in Chile. IFOP also distributed batter-dipped krill sticks in 1977 at a trade fair in Germany (FRG). IFOP determined that a commercial krill fishery was economically feasible with existing technology and attempted to turn the results of its research over to Chilean investors in 1976 and 1977, but was unable to find a company willing to make the necessary investments.

The Chilean Antarctic Institute (INACH) resumed krill research in 1981. INACH carried out three more cruises, using the *Itzumi* (1981) and the *Capitan Alazar* (1984 and 1985). These cruises were conducted as part of the international research programs conducted in the Antarctic, the First International Biomass Experiment (FIBEX) and the Second International Biomass Experiment (SIBEX) (Table 1).

Chile cooperates with several countries on Antarctic research. China, which wishes to establish a claim to Antarctic activities, has recently approached Chile concerning cooperative research. China has a research station on King George Island, within the Chilean territorial claim. It is believed that the Chinese are primarily concerned with ocean minerals, but some research on krill may be also conducted.

Table 2.—World catch of Antarctic krill, 1980-85.

Nation	Catch (1,000 t)					
	1980	1981	1982	1983	1984	1985
U.S.S.R.	440.7	420.4	491.7	180.3	74.4	
Japan	37.8	27.8	35.2	42.5[1]	49.6[1]	40.0E[2,3]
Rep. of Korea			1.4	2.0	2.7	
Chile			0.5	4.9	1.6	2.8E
Poland	0.2			0.4		
France	Negl.					
Total[4]	478.7	448.3	528.8	230.0	128.3	NA

[1]This data differs from a report in the *Suisan-Keisai*, 8 November 1985, which reported 32,000 t for the 1983-84 season, 20,400 t for 1984-85, and 25,950 t planned for 1985-86, perhaps because their figures represent krill weight after processing, excluding that portion of the catch reduced to krill meal.
[2]E = Estimated from 1982-85 total published in *Chile Pesquero*, December 1985; NA = Not Available.
[3]Precise data is not available, but most published sources suggest the catch declined in 1985.
[4]Totals may not agree due to rounding.

Catches

IFOP's research work in 1974-76 was not immediately followed by a commercial fishery. Development of an actual krill fishery did not begin until a Chilean subsidiary of a Japanese fishing company launched an exploratory cruise in 1982 which landed about 500 t. The company followed up with a first commercial fishing in 1983 and landed about 4,900 tons, making Chile the world's third leading krill fishing country in that year after the Soviet Union and Japan (Table 2). Chilean companies reduced fishing effort in 1984 and the krill catch declined to only 1,600 t, dropping Chile to fourth place in the world krill fishery (Table 2). The decline reportedly resulted primarily from company decisions adjusting fishing effort to existing

[1]A good summary of available information on the biology of Antarctic species, including krill, is J. L. Bengtson's "Review of Information Regarding the Conservation of Living Resources of the Antarctic Marine Ecosystem," Univ. Minn., July 1978 (currently being updated). The major review of krill biology is J. W. S. Marr's "The Natural History and Geography of the Antarctic Krill (*E. superba*)," Discovery Rep. 32:33-464. Another monograph summarizing the krill potential is J. D. Kaylor and R. L. Learson's "Krill and Its Utilization: A Review," NOAA Tech. Rep. NMFS SSRF 769, July 1983, 10 p.

market demand and not from the availability of the resource. The Japanese companies which market the Chilean catch were concerned that the market could not absorb too large a catch which might cause a sharp price decline.

Press reports suggest that Chile increased krill catches to an estimated 2,800 t in 1985. Precise 1985 data, however, was not yet available for the other countries fishing krill but unconfirmed reports suggested that Chile probably continued its fourth place ranking. Press reports also suggested that in 1986 or 1987, a fifth country, Poland, would enter the Antarctic krill fishery. IFOP officials believe that Chile's small catch could easily be increased to 100,000 t, or more, during the next 10 years, based only on catches off the Antarctic Peninsula south of Chile and Argentina. IFOP projects that a catch of about 1.0-1.5 million t could eventually be possible.

Almost the entire Chilean catch is frozen whole aboard the vessel (Table 3). Actual procedures of the Chilean subsidiaries are unknown, but they probably follow the pattern of the Japanese vessels active in the fishery. The Japanese primarily process whole frozen krill. Most is frozen raw, but an increasingly large percentage is being boiled first. The Japanese are also increasing the production of peeled krill (Table 4). The meal is produced from krill which is not in good enough condition to process as an edible product and the offal which results from peeling the krill.

Table 3.—Chile's production and exports of Antarctic krill products by commodity, 1982-84.

	Production (1,000 t)			Exports (1,000 t)		
Year	Frozen	Meal	Total	Frozen	Meal	Total
1982	0.4	Negl.		NA	NA	NA
1983	2.9	0.2	3.1	2.3	0.1	2.4
1984	1.4		1.4	1.3	0.1	1.4

Source: Servicio Nacional de Pesca, "Annuario Estadistico de Pesca," 1982-84. NA = Not available.

Table 4.—Japan's frozen krill production by commodity, 1984-86.

	Amt. (1,000 t)	
Commodity	1984-85	1985-86
Whole		
Raw	15.7	15.6P[1]
Boiled	4.2	7.3P
Peeled	0.5	3.1P
Total	20.4	26.0

[1]P = Planned.

Companies

Chile's krill fishery has been developed by subsidiaries of two Japanese companies[2]. Press reports in the late 1970's suggested that various Japanese and European countries (France, Spain, and others) were considering investments in Chile to develop a krill fishery, but only the Japanese have pursued the opportunity. The two Chilean subsidiaries of Japanese companies currently fishing krill are: Empresa de Desarrollo Pesquero (EMDEPES) and Nichiro Chile. EMDEPES is a subsidiary of Nippon Suisan Kaisha Ltd. (NSK) and Nichiro Chile is a subsidiary of Nichiro Gyogyo Kaisha Ltd. (NGK). The two Chilean subsidiaries have each deployed a factory vessel in the fishery and have a combined work force of 150 employees. EMDEPES began the commercial fishery in 1983 and was followed by Nichiro Chile in 1984. The two companies normally deploy their vessels in the fishery for hake and other demersal species off southern Chile, but for 2 months during the Antarctic summer, one or two vessels are deployed for krill.

Government Promotion

IFOP has been promoting Chile's krill fishery since 1974. At the request of the Chilean Government, IFOP has devised a strategy for developing a large krill fishery by 1991. As part of that strategy, IFOP has prepared investment studies to provide interested foreign companies details on the feasibility of investing in the krill fishery. IFOP held a seminar on "Chile and the Fishery for Antarctic Krill" during October 1985. The seminar was attended by various Chilean Government and private industry specialists and dealt with: Chile's Antarctic program; international legal problems; climatic, oceanographic, and biological factors; and technical and economic aspects of fishing and processing krill. CORFO Deputy Director, Brigadier Fernando Hormazabal, inaugurated the seminar and stressed the importance of krill in Chile's overall Antarctic policy.

Marketing

Chile is the leading fishing country in Latin America. While most of the catch is reduced to fishmeal, a wide variety of high-quality seafood products is available to Chilean consumers. As a result, Chile has one of the highest levels of seafood consumption in Latin America, 15.8 kg per capita (live weight equivalent), about the same as in the United States. Chilean companies will thus find it difficult to introduce krill into the Chilean market unless they can develop an unusually attractive product or one that is very inexpensive. Small quantities probably could be sold in some of the product forms developed by IFOP, but any commercial success would necessitate reducing the cost of producing krill.

This limited domestic potential and the country's small population (about 12 million, 1985 data) suggest that only limited quantities of edible krill products can be marketed domestically. Local observers note, however, that Chile has begun to develop a salmon culture industry. Although current salmon production is small (about 600 t in 1985), the country's potential is much larger. Chile has the potential to build a sizeable aquaculture industry based on salmon and several other species. As this industry develops, a market may grow in Chile for fish feed made from krill.

The primary market for any major Chilean krill fishery would have to be in foreign countries, especially in Japan. Both EMDEPES and Nichiro Chile currently export their entire krill catch to Japan. The market for krill in Japan, however, is just beginning to develop. NSK, for example, has developed more than 40 different krill products, but sales have reportedly been poor. Both Chilean companies export the krill whole without processing it in Chile (Table 3). They receive about $350 per ton. The krill is then processed in Japan into various edible products. One Japanese executive believes that current krill

[2]Mention of trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

prices could drop as much as 35 percent unless the companies involved carefully limit production of both domestic and Antarctic krill[3]. Japanese companies have been carefully monitoring inventories and market demands. As a result, those companies reduced purchases in both Chile and Korea during the 1984-85 season (Table 5).

Most of Japan's krill is marketed frozen (Table 4) in both edible and inedible forms. Data on consumption by commodity is not available, but unconfirmed reports suggest that most of the krill is utilized to produce inedible products.

Edible Products

The major edible krill products are primarily frozen whole krill, peeled and dried krill meats in shrimp-like presentations, and a small quantity of paste. A small boiled shrimp (sagura-ebi) is popular in Japan, and krill is being marketed as a less expensive substitute. Nippon Suisan has reportedly begun to can krill for Japan's school lunch program. Japan has also done considerable research on using krill to make surimi or a solvent extracted protein concentrate (marine beef), but these projects are still at the research level. Unconfirmed reports suggest that there is increasing interest in edible krill products in Japan.

Inedible Products

The major inedible products are frozen krill and meal for fish feed. One unconfirmed report indicates that more than half of Japan's krill catch is marketed frozen for fish feed in Japan's expanding aquaculture industry or for bait in Japan's popular recreational fishery. Meal produced from krill is used for fish feed. Krill meal reportedly commands high prices. The demand for krill fish feed is likely to increase as most observers believe that Japan's aquaculture industry is likely to continue expanding for the foreseeable future. Krill has proven a valuable dietary supplement for species such as salmon, sea bream, and kuruma shrimp. Carotenoids in the krill, rich in vitamin A, also enhance the red color of the flesh of salmon and other species which makes the harvested fish more marketable to color-conscious Japanese consumers.

IFOP officials report that Chile exported 2,000 t of krill worth $1 million in 1983, although shipments declined in 1984. Officials believe that shipments could be increased to $50-70 million in 1995. Increases of that magnitude, however, will depend on the development of krill products in Japan and other export markets. A great deal more product and market development will have to take place before the Chilean fishery can expand along the lines projected by IFOP.

Currently, the use of krill for many product forms is not possible because of the high fishing costs, low meat yields, and lack of suitable products for the offal. Until more progress is made in these areas, significantly increased krill fishing is unlikely. The Soviet Union and Japan, the two major krill fishing countries, have reduced their fishing effort. The Soviet Union sharply reduced krill catches in 1983 and 1984. Unconfirmed reports suggest that the Soviets reduced their fishing effort for a variety of reasons: The retirement of many older vessels, low demand for such edible krill products as pastes, quality control problems including high chlorine levels in krill products, and complications in the use of krill meal for animal feed[4]. The Japanese reduced their fishing effort during the 1984-85 season, but were planning to increase effort during the 1985-86 season (Table 5). Japanese observers report that the companies involved are only beginning to develop edible krill products and they are concerned that an over supply of krill could cause prices to decline precipitiously, especially given the limited size of the existing market.

Table 5.—Japan's krill supply and fishing effort, 1983-86.

Item	Supply (1,000 t) 1983-84	1984-85	1985-86
Antarctic krill			
Catch	32.0	20.4	30.0P[1]
Imports			
Chile	3.5	1.2	1.2P
Korea	1.5	Negl.	
U.S.S.R.	Negl.	Negl.	
Inventory	8.0	20.0	12.0P
Domestic krill			
Catch	65.0	50.0	NA
Inventory	15.0	20.0	20.0P
Total supply	125.0	111.6	NA
Effort: No. of trawlers	10	7	9P

[1]P = Planned, NA = Not available.

Economic Factors

IFOP believes that the development of Chile's krill fishery will probably rely primarily on importing used factory trawlers. The cost of initiating a krill fishing company is about $6.7 million, $6.0 million for the factory vessel and $0.7 million for working capital. Since krill fishing is only possible for about 5 or 6 months each year (November to April or May), krill ventures require alternative fisheries for the rest of the year. Two possible alternatives for krill fishing operations off the southern coast of South America include cephalopod fishing off Argentina or mackerel fishing off Chile. The two existing Chilean krill companies currently participate in the trawl fishery for demersal species off southern Chile. Chilean fishermen, however, have begun to criticize the Government's policy of allowing foreign companies to participate in the southern trawl fishery, so new significant demersal allocations for foreign fishermen are unlikely.

Chile would like to attract foreign investors to help fund new companies to catch and process krill. IFOP has prepared a feasibility study on krill fishing and has advertised for interested foreign companies with capital and technological capabilities.

New Development Law

The Chilean Government enacted a new law (Number 18,392) on 14 January 1985 to promote economic development south of the Straits of Magellan. The law applies only to shore-based facilities which are of little benefit to Chilean investors because companies would probably follow the existing system of using factory vessels and exporting whole frozen krill without processing the catch

[3]Press reports of 8 November 1985, quoted prices of about ¥100/kg domestic krill and ¥200/kg of Antarctic krill; the U.S. dollar was then trading for about ¥200.

[4]The Soviets have noted a sharp decline in the fecundity of pigs given feed with a high krill content. As a result they have reportedly restricted the use of krill meal to produce feeds for fur producing animals.

in Chile. The law could, however, benefit Chilean companies which begin to process krill in Chile. As the industry develops, it may be able to convince Government officials to modify the provisions restricting the benefits of the law to onshore facilities.

Antarctic Convention

Chile has both a territorial claim in the Antarctic (D.S. 1,747, made 5 Nov. 1940) (Fig. 2) and is a signatory of the Convention for the Conservation of the Antarctic Marine Living Resources (CCAMLR) which has as its primary objective the conservation and rational use of marine fauna within the Antarctic Convergence. CCAMLR, through its Scientific Committee (SC) can establish various resource management procedures (set quotas and area and gear restrictions). Signatory CCAMLR countries can also unilaterally require their own fishermen to follow management measures which best satisfy their economic and/or political interest, as long as they are consistent with CCAMLR management objectives.

The Soviet Union and Japan (both CCAMLR signatories) have been the most active since the beginning of the fishery in 1976. Because historic rights are based on the Law of the Sea provisions, if a quota-by-area system were established, these two countries might claim historic rights over important fishing areas within the Antarctic Convergence.

The Soviets began fishing for krill in 1961. Until 1983, the Soviets had been catching over 400,000 t of krill annually, more than 90 percent of reported world krill catches. Soviet catches, however, declined to only 74,400 t in 1984 (Table 2). Japanese fishermen have reported a smaller, but more stable fishing pattern. Japanese catches in the 1980's have varied from a low of 27,800 t in 1981 to a high of 49,600 t in 1984. Several other countries reported experimental catches in the 1970's and 1980's, but only the Soviet Union and Japan have demonstrated significant, sustained commercial fishing operations.

Filippi Parada, Executive Secretary of the Chilean section of CCAMLR, is increasingly concerned over Chilean rights to fish in Antarctic waters. He believes that the Soviet and Japanese fishing efforts may be used to demonstrate historic krill fishing rights in future negotiations over the Antarctic. As a result, Chilean officials are convinced that it is important for Chile to establish a commercial krill fishery so that it can also make a case for historic fishing rights. Francisco Ramirez, Vice President of CORFO, confirmed that the Chilean fishery will "permit Chile to solidly establish its claims of sovereignty (in the Antarctic)..." (Source: IFR-86/70.)

Japan's 1985 Fish Production Second Highest on Record

Japan's annual landings of fisheries and fish culture products for 1985 totaled 12,197,000 metric tons (t), a 5 percent decline from the historical high landings of 12,793,000 t in 1984. Distant-water and offshore fisheries production declined 8 and 6 percent, respectively, while inland fisheries production rose 3 percent. Production from coastal fisheries, marine culture, and inland culture were relatively stable.

By species, significant gains were recorded in the catches of herring (+43 percent), pink salmon (+36 percent), and large yellowfin (+17 percent), whereas sharp declines occurred in rockfish (−33 percent), skipjack (−29 percent), common squid (−28 percent), yellowtail (−20 percent), and bluefin tuna (−17 percent). The most important species landed in terms of quantity was sardine, with a catch of 4,242,000 t, followed by Alaska pollock with 1,511,000 t, and Pacific mackerel with 779,000 t. Sardine, Alaska pollock, and Pacific mackerel together accounted for 57 percent of Japan's total marine fisheries catch for 1985. The landings by major fisheries and species are shown in Tables 1 and 2.

Table 1.—Japan's catch by type of fishery 1979-85.

	Catch (1,000 t)						
Fishery	1979	1980	1981	1982	1983	1984	1985
Marine fisheries							
Distant-water	2,066	2,167	2,165	2,089	2,127	2,263	2,077
Offshore	5,458	5,705	5,939	6,070	6,433	6,937	6,547
Coastal	1,953	2,037	2,038	2,072	2,137	2,281	2,283
Marine culture	883	992	960	938	1,060	1,107	1,083
Inland fisheries	136	128	124	122	117	107	110
Inland culture	95	94	92	96	94	99	97
Total[1]	10,590	11,122	11,319	11,388	11,967	12,793	12,197

[1]May not add due to rounding.

Table 2.—Japan's marine fisheries catch by selected species, 1984-85.

	Catch (1,000 t)			Catch (1,000 t)	
Species	1984	1985	Species	1984	1985
Tuna			Cod		
Bluefin	36	30	Cod	114	136
Albacore	64	59	Alaska pollock	1,621	1,511
Bigeye	131	148	Subtotal	1,735	1,647
Yellowfin, large	115	134	Mackerel, Pacific	814	779
Yellowfin, small	19	20	Flatfish	257	210
Subtotal	365	391	Rockfish	15	10
Skipjack			Hairtail	34	31
Skipjack	446	316	Herring	7	10
Frigate mackerel	21	24	Red snapper	16	15
Subtotal	467	340	Sardine	4,513	4,242
Billfish	49	48	Sandlance	184	128
Shark	35	34	Saury	210	243
Salmon (excluding pinks)	136	171	Yellowtail	41	33
Salmon, pink	22	30	Squid, common	174	125
Mackerel, Jack	136	152	Octopus	43	40
Mackerel, scad	98	73	Shrimp	61	53
Mackerel, Atka	66	68			

New NMFS Scientific Reports Published

Some publications listed below may be sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Copies of all are sold by the National Technical Information Service, Springfield, VA 22151. Writing to either agency prior to ordering is advisable to determine availability and price (prices may change and prepayment is required).

NOAA Technical Report NMFS 36. Lasker, Reuben (editor). **"An egg production method for estimating spawning biomass of pelagic fish: Application to the northern anchovy, *Engraulis mordax*."** December 1985, iii + 99 p. (15 papers).

ABSTRACT

The chief advantages of this egg production method are that 1) it yields an instantaneous estimate of egg production and spawning biomass requiring a single cruise with one or two ships and 2) each factor in the biomass estimate is formally derived with estimates of precision. The major disadvantage of the method is that eggs are patchier and represent a shorter time period than larvae, thus requiring many samples to be taken to improve precision. Each sample must be small to reduce variance and to limit the time needed to sort out the eggs, and the entire spawning area should be encompassed by the cruise to detect the geographic edge of spawning. The egg production method may also be the technique of choice for determining the spawning biomass of other multiple spawning pelagic fish, particularly clupeoids (e.g., sardine, anchovy, and menhaden), and this report is intended to be a guide to fishery scientists in applying the method to their own species. It provides the theoretical basis and describes the operational aspects of the method as used to determine the spawning biomass of the northern anchovy, *Engraulis mordax*, off California in the last 5 years.

NOAA Technical Report NMFS 37. Murchelano, Robert A., Linda Despres-Patanjo, and John Ziskowski. **"A histopathologic evaluation of gross lesions excised from commercially important north Atlantic marine fishes."** March 1986, iii + 14 p., 13 figs., 4 tables.

ABSTRACT

Histopathologic studies of lesions found in commercially important North Atlantic marine fishes are uncommon. As part of a comprehensive Northeast Fisheries Center program ("Ocean Pulse") to evaluate environmental and resource health on the U.S. Continental Shelf from Cape Hatteras to Nova Scotia, grossly visible lesions of the gills, integument, muscle, and viscera of primarily bottom-dwelling fishes were excised and examined using light microscopy.

Several gadid and pleuronectid fishes accounted for most of the lesions observed. Most pathological examinations were incidental to samples taken for age and growth determination and evaluation of predator/prey relationships. Several gadids, with either gill, heart, or spleen lesions, were sampled more intensively. Gill lesions principally affected gadids and were caused by either microsporidans or an unidentified oocyte-like cell. The majority of gastrointestinal lesions consisted of encapsulated or encysted larval worms or microsporidan-induced cysts. Few heart lesions were found. Integumental lesions included ulcers, lymphocystis, and trematode metacercariae. Liver lesions almost always consisted of encapsulated or encysted larval helminths. Necrotic granulomata were seen in muscle and microsporidan-induced granulomata in spleen.

A Field Guide to Alaska's Marine Life

Publication of **"Alaska's Saltwater Fishes and Other Sea Life"** has been announced by the Alaska Northwest Publishing Company, 130 Second Avenue South, Edmonds, WA 98020. The author is Doyne W. Kessler, a fisheries biologist with the Kodiak Laboratory of the NMFS Northwest and Alaska Fisheries Center.

This is a genuine "field" guide for specialists and nonspecialists to the quick identification of the marine creatures off Alaska's shores. The author presents in full color most of the fishes and invertebrates of the region, with the primary sampling region being roughly from the waters of Kodiak Island through Unimak Pass and past the Pribilof Islands to lat. 59°N. The photographs are quite good and were expressly made under standardized and strictly controlled conditions to show the true color, form, and texture of live creatures. These and other diagrams and text guide the user to 370 species, many never before identified and photographed.

Rarely are field guides field tested before publication as this one was, with looseleaf versions with color prints being employed and refined in actual shipboard use. The book, developed over 15 years, includes only the data needed for positive identifications, and simplifies identification by emphasizing the distinguishing features of the living animals such as shape, color, surface texture, etc. It employs a "picture index," instead of a scientific key, to lead users to the proper section for final identification, where the color photos, coupled with key identification marks facilitate final identification. General size and range data are also listed. For data on life history, commercial usage, ecology, etc., readers are referred to other literature sources in the guide's bibliography. Besides the picture "index," the volume has indexes to both common and scientific names.

Thus it is a unique and excellent contribution to the field identification of the marine life of Alaska's continental shelf waters, which should be very useful to the region's scientists, commercial and recreational fishermen, as well as others interested in marine life further south. Paperbound, the 358-page volume is available from the publisher for $19.95 ($24.95 in Canada).

The Effects of El Niño

"El Niño North," subtitled "Niño effects in the eastern subarctic Pacific Ocean" and edited by Warren S. Wooster and David L. Fluharty, has been published by the University of Washington Sea Grant Program, 3716

Although not numerous, histologically interesting lesions were noted in integument, heart, liver, spleen, and muscle of several fish species. Histologic study of tissues excised from a variety of demersal and pelagic fishes from the eastern North Atlantic (France, Germany, Spain) revealed assorted integumental, renal, hepatic, and splenic lesions. Small sample size and non-random sampling precluded obtaining a meaningful quantitative estimate of the prevalence of the observed lesions in the population at risk; however, a useful census has been made of the types of lesions present in commercially important marine fishes.

NOAA Technical Report NMFS 38. Uchida, Richard N., and James H. Uchiyama (editors). **"Fishery atlas of the northwestern Hawaiian Islands."** September 1986, iii + 142 p., 77 figs., 5 tables.

ABSTRACT

This atlas summarizes data on the crustaceans, molluscs, and fishes caught in a resource survey of the northwestern Hawaiian Islands from October 1976 to September 1981. The geographical and depth distributions, size range, and the type of gear used to catch all of the crustaceans, molluscs, and fishes are tabulated. Species accounts of 37 crustaceans, molluscs, and fishes of commercial potential are presented. The geography, oceanography, and climate of the region are reviewed.

Brooklyn Ave., N.E., Seattle, WA 98105. The volume is a compilation of papers presented at a meeting on the 1982-83 El Niño held in September 1984 at NOAA's Pacific Marine Environmental Laboratory, Seattle, Wash., and sponsored by IRIS (International Recruitment Investigations in the Subarctic) and supported by the NMFS Northwest and Alaska Fisheries Center. All of the papers were refereed; a few are abstracts of papers published elsewhere. But overall, the publication represents a significant record of how a major El Niño event can perturb the ocean and its biota so far north, and also suggests additional research which might help predict the effects of future El Niño episodes.

The papers in part one focus on the physical environment affected from the tropical Pacific to the eastern Bering Sea and the western North Pacific. Contributions in part two examine the biological response—plankton and nekton distribution and abundances, effects on the early life history and recruitment of fishes in temperate marine waters, zooplankton and ichthyoplankton responses off Oregon, effects on Oregon seabirds, salmon management in response to the El Niño, records and sightings of fish and invertebrates in the eastern Gulf of Alaska, and others. The collection of papers should form an important reference to the 1982-83 El Niño phenomenon; also included is a selected bibliography of El Niño events in the eastern subartic Pacific Ocean. Paperbound, the 312-page volume is available from the publisher for US$10.00.

THE ROLE OF SEAFOOD IN HUMAN HEALTH

The **"Proceedings of Seafood & Health '85, Issues, Questions, Answers"** has been published by the West Coast Fisheries Development Foundation, 812 S.W. Washington, Suite 900, Portland, OR 97205. The Foundation also has available a complete videotape of the conference—five 90-minute tapes covering all the talks in 1/2-inch VHS or Beta formats.

The conference, held in Seattle, Wash., in late 1985 brought together some of the nation's leading medical researchers, nutritionists, dietitians, seafood marketers, seafood industry representatives, and communicators from the trade and popular press to discuss the healthful benefits derived from eating fish and how to better and more effectively promote fish in the American diet. Thus, the contributions review what is known about the health benefits of eating seafood, dietary trends in the United States, nutrient composition of seafoods, the effects of omega-3 (n-3) and other fatty acids and sterols in the diet, the politics of seafood promotion, antithrombotic effects of the omega-3 fatty acids, and impact of omega-3 fatty acids on prostaglandin synthesis and disease mechanisms, relationships between seafood and diet and breast cancer, new frontiers of research in fish oils, and dietary recommendations to the public.

Discussions on the second day reviewed communicating about nutrition questions, the seafood industry's perspective on seafood and health, where to get good information on seafood and nutrition, retail promotion of seafood, advertiser responsibilities, and the role of food writers and editors in promoting seafoods. The book also includes important segments of discussions surrounding the presentations.

Overall, the proceedings (and the conference) presented an excellent mix of technical data on the healthful benefits from eating seafoods to ways to better communicate those values to the American consumer and it will be of interest and use to a wide range of professionals involved in studying, managing and communicating facts about the role of seafoods in a healthful diet. The 220-page paperbound volume is available from the Foundation for $50.00 and the videotapes cost $125.00 per set.

Also published by the foundation is a seafood supplier guide, titled **"Who hazzit,"** listing seafood firms in Washington, Oregon, and California who wish to expand into new markets, their products and species and marketing forms. The directory lists contacts for each firm and costs $15.00.

International Game Fish Annual and Record Book

"World Record Game Fishes 1986," published by the International Game Fish Association, 3000 E. Las Olas Blvd., Fort Lauderdale, FL 33316-1616, presents another set of excellent conservation-oriented articles for marine anglers along with the listings of world game fish records approved by IGFA during 1985, which was a very good year. World records granted were 694, second only to the all-time high of 1,074 set in 1984. In addition, the volume updates the records listings in all-tackle, line class, and tippet class categories for more than 150 species of both fresh and saltwater fishes. The listing also reflects the expansion of the number of species recognized for records listings.

New articles include a description of how anglers can increase their fishing efficiency by employing satellite data by Mitchell Roffer, along with two articles on fisheries enhancement: Daniel Sheehy's discussion of the transfer of east Asian artificial reef and fish attrac-

tor technology and Richard Brock's article on how fish habitat can be enhanced for fish and anglers. In addition Carol Hopper describes her studies of marlin reproduction, in conjunction with the Hawaiian billfishing tournaments, and how her findings may help achieve better resource management. Two other reports—one on acid rain problems by Patricia Bradt and Dean Arnold and the other marine debris pollution by NMFS scientist Howard O. Yoshida—provide excellent insights into two serious problems facing anglers and fish. Finally, Peter Fithian discusses the what, where, when, why, and how of "fishing contests."

In addition, the volume presents the usual data on angling rules, world record requirements, contest and club requirements, and other Association data, along with the "guide to fishes" section, plus appendices on fish record-keeping agencies, fishing knots, and an index by common and scientific names of fishes. The volume is free to IGFA members and is sold to others for $9.75 (in U.S.A.) and $11.75 (foreign).

The Marine Fishes of European Waters

Publication of Volume I of **"Fishes of the North-eastern Atlantic and the Mediterranean,"** edited by P. J. P. Whitehead, M.-L. Bauchot, J.-C. Hureau, J. Nielsen, and E. Tortonese, has been announced by Unesco, Division of Marine Sciences, 7 Place de Fontenoy, 75700 Paris, France. The first of three volumes (the last to appear in early 1987), this book constitutes an important major guide to the marine fishes of Europe's waters and an important ichthyological reference. Whitehead, chief editor of the series, is Head of the Marine Fishes Section of the British Museum (Natural History) and a Vice-President of the European Ichthyological Union. Bauchot and Hureau are Professors at the Museum National d'Historie Naturelle, Nielsen is Curator of Fishes at the Zoologisk Museet in Copenhagen, and Tortonese is Honorary Director of the Museo Civico di Storia Naturle in Genova. The book covers broadly from the Mediterranean to Madiera, the Azores, and north to Greenland and eastward to Novaya Zemlya. The volume(s) are a result of >20 years of preparation by more than 70 scientists from nearly 20 countries.

Short title for the three-volume series is FNAM, which is an extension of CLOFNAM, the "Check-list of the Fishes of the North-eastern Atlantic and of the Mediterranean," published in two volumes in 1973, with a second reprinting with a supplement in 1979. CLOFNAM, as an intermediate step toward the new publications, remains a complementary resource to users of FNAM.

Europe's marine fishes are among the most and best studied in the world, but FNAM is the only single work to include comprehensive data on them all, including distribution, biology, as well as keys to them and drawings to facilitate identification. Indeed, this impressive new reference includes the main taxonomic features and biology of all of the known marine fishes of the region—altogether 1,256 species from 218 families. It includes diagnostic keys to families, genera, and species, as well as details on nomenclature, external morphology, reproduction, food, habitat, and maps illustrating geographical distribution. An excellent drawing of each species is presented, and references are thorough.

The family key, valid only for the specified region, includes a representative drawing. Only common synonyms are given (full synonym lists and their literature references are in CLOFNAM); common names are most often given in English, French, and Spanish per FAO listings; some German and Russian and other national names are included as needed. Families included in Volume I range from Petromyzonidae (CLOFNAM 1) through Anotopteridae (CLOFNAM 64).

All species are included from all habitats, including estuaries, lagoons and brackish waters, and from the continental shelves on down to the abyssal depths. The editors and authors have also retained the CLOFNAM family, generic, and species numbers to ease data retrieval and aid those who have adopted the CLOFNAM numbers for museum storage or indexing purposes, while bringing the classification up to date.

Volume I, currently available, contains the lengthy illustrated key to the families; Volume III, when published, will contain the indexes by common and scientific names. This comprehensive work will be of great value to anyone needing information on the region's fishes and should serve as a standard reference for many years for students, biologists, and research scientists, as well as nonspecialists seeking information on Europe's marine fishes.

Hardbound, the 510-page Volume I is available worldwide from Unesco book distributors. In the United States it is available for $63.50 from Unipub, P.O. Box 1222, Ann Arbor, MI 48106; in England from HMSO, P.O. Box 276, London, SW8 5DT for £37.50; and in France and elsewhere from the Librairie de l'Unesco, 7 Place de Fontenoy, 75700, Paris, for FF250.

A Comprehensive Review of Seafood Utilization

"The Northeast Seafood Book," subtitled "A manual of seafood products, marketing and utilization" and written by Susan M. Faria, has been published by the Massachusetts Division of Marine Fisheries, New England Fisheries Development Foundation, and the Northeast Marine Advisory Council. The author is a marketing specialist with the Seafood Marketing Program of the Massachusetts Division of Marine Fisheries. The book was originally written to provide practical and reference information on northeastern U.S. seafoods for home economists, extension agents, and the like, but was vastly expanded to include information useful to virtually all those involved in the seafood industry.

Introductory topics include U.S. seafood consumption and attitudes, seafood industry trends, fisheries management, aquaculture, commercial fishing, fish processing, fish distribution and marketing, Federal inspection and grading of fishery products, seafood pricing, and frozen, cured, and canned seafood products. Also discussed is roe (and caviar), minced fish, surimi, seaweeds, sashimi, and sushi, as well as industrial fishery products. Additional sections review the nutritional aspects of seafoods, public health concerns, seafood quality, and

tips for buying and storing seafoods.

In addition, the author has provided excellent sections on seafood cooking methods plus a "how to" section dealing with items ranging from steaking, filleting, and skinning fish to the handling of shellfish, including squid, home preparation of caviar and sushi, boning out round and flatfish, stuffing large round fish, and the home salting, smoking, pickling, and canning of fish. Another section provides instruction in teaching others about seafood and sources of data and literature. Finally, a length section is devoted to data on northeastern U.S. seafoods. Another on "nonnative" seafoods greatly broadens the scope and usefulness of the volume. Also included is a seafood nutritional composition table, conversion ratios for shellfish (mussels or clams per bushel, etc.), and a glossary.

The volume is an excellent reference source that even most homemakers would find very useful, although it has been aimed at an audience of restauranteurs, food service operators, home economists and other educators, and seafood retailers, wholesalers, and distributors. Paperbound, the 269-page volume is available from the Northeast Marine Advisory Council, NEC Administration Building, 15 Garrison Avenue, Durham, NH 03824 for $15.00.

International Angling Problems and Progress

"World Angling Resources and Challenges," edited by Richard H. Stroud, constitutes the Proceedings of the First World Angling Conference which was held in Cap d'Agde, France in September 1984, by the International Game Fish Association (IGFA), 3000 East Las Olas Blvd., Ft. Lauderdale, FL 33316-1616. Contributing sponsors included the U.S. Department of Commerce's National Marine Fisheries Service, the Interior Department's U.S. Fish and Wildlife Service, and Canada's Department of Fisheries and Oceans.

The conference's first session, and the Proceedings' first hundred pages, are devoted to a review of various national or regional angling reports on the species available, fishing organizations, angling (fishing) resources, types of angling available and methods, and much more. For some nations the reports are necessarily brief, but for many, much useful information is provided.

The second session presents several fine reports on fisheries habitat—types needed, problems causing fish habitat losses or degradation (i.e., acid rain in Europe and Canada; sources and effects of various contaminants, etc.), and a call by Douglas S. Dallas to sportsmen to guard their angling heritage.

Session three then presented several avenues through which angling resources could be enhanced—via habitat restoration, use of cultured fishes, and by constructing artificial reefs and fish aggregating devices. The following session provided several insights into the needs for and uses of research and data requirements for management, an economic evaluation of sport fishing, a look at the diversity among recreational fishermen, the importance of cooperative game fish tagging programs in marine fisheries research, tagging game fish in the Indo-Pacific region, a review of the transatlantic migrations of the blue shark, and a plea for angler-scientist cooperation and an international inventory of marine sport fishes.

Session five presented status reports on the Atlantic bluefin tuna resource, world billfish stocks, and a review of Pacific salmon management in Canada. Session six, problems and opportunities in managing recreational fisheries, reviewed a number of knotty problems. Papers included a basic review of why and how fisheries should or could be managed, the international management of tunas and billfishes and Atlantic salmon, and a discussion of the means of funding recreational fishing programs in the United States.

The final session presented a discussion on marine recreational fishing development, an overview of angling contests, a short review of fishing clubs (especially university clubs), and the role of industry in recreational fisheries —all generally directed at fisheries development. The final article reviewed the nutritive values of fish, as opposed to the esthetic values in angling for them.

The volume is thus an excellent source of information on worldwide game fish and angling and the problems besetting anglers and their quarry. However, it also provides some good suggestions for developing or improving the resource and the sport. It unfortunately lacks an index, but otherwise will be a very valuable reference for those involved in recreational fishing, either as an angler or as a fishery biologist, manager, or administrator. The 390-page volume, hardbound, costs $25 in the United States and $30 elsewhere.

Sturgeon, Carp Culture, and Fish Disease Reviews

Publication of **"Recent Advances in Aquaculture, Volume 2,"** edited by James F. Muir and Ronald J. Roberts, has been announced by Westview Press, 5500 Central Avenue, Boulder, CO 80301. Contributions by authorities from four continents emphasize nutrition and diseases of farmed fish, along with an interesting chapter on sturgeon culture which describes both the traditional Russian system and innovations in white sturgeon culture in California.

Chapter 1 constitutes a review of the fish parasite *Ichthyobodo necator*, a kinetoplastid in the family Bodonidae. Discussed is the protozoan flagellate's biology and life history, host-parasite interactions, environmental effects on infestations, and chemical treatments for it. Chapter 2 then reviews egg development (oogenesis) in the common carp, *Cyprinus carpio*, and chapter 3 reviews smoltification physiology in the culture of salmonids.

Chapter 4 presents a lengthy discussion of the biology and culture of the grass carp, *Ctenopharyngodon idella*, with special reference to its utilization for weed control; appended is a listing by E. M. Ebregt of parasitic agents reported from the species. In chapter 5, diseases induced by the mold *Aspergillus* are reviewed, along with possible control methods. In chapter 6, Simon J. Davies outlines the role of dietary fiber in fish nutrition, including fiber in natural ingredient diets, studies using alpha-cellulose, chitin as a fiber source, and the experimental use of galactomannan as a gel-fiber.

Finally, in chapter 7, Sergei I. Doroshov reviews the biology and culture of sturgeons, and discusses life history

aspects of several important species. He then explains approaches to sturgeon culture, sturgeon "ranching" in the Soviet Union, hatchery techniques, and grow-out to market size; much, he adds, remains to be learned about the species and their culture. Indexed, the 282-page hardbound volume is available from the publisher for $42.00.

Olfaction, Taste, and Their Use by Finfish

Volume 8 in the series Developments in Aquaculture and Fisheries Science is **"Chemoreception in Fishes,"** edited by Toshiaki J. Hara and published by Elsevier Scientific Publishing Company, P.O. Box 330, 1000 AH Amsterdam, The Netherlands. Research in the field has grown rapidly in recent years and indeed, has special application in the development of effective fish bait, in understanding fish migration, social behavior, and feeding, effects of pollution on fishes, and more.

This volume broadly reviews chemoreception with special emphasis on its significance in behavior and in environmental interactions. Its 21 chapters are divided into five categories: Organ structure and function, chemoreceptive mechanisms, role of chemoreception in feeding, role of chemoreception in social behavior and migration, and chemoreception and water pollution.

An initial chapter by H. Kleerekoper presents an interesting historical review of the studies and ideas on olfaction in fishes from the 18th to the early 20th century. Subsequent chapters discuss development and regeneration of the olfactory organ in rainbow trout, comparative morphology of the peripheral olfactory organ in teleosts, synaptic organization of the olfactory bulb and central projection of the olfactory tract, and the taste organ in the barbel of the bullhead. Additional chapters review the role of olfaction in the orientation of fishes, chemoreception in the lateral-line organ, responses of olfactory receptor cells to electrical and chemical stimulation, and amino acids as olfactory stimuli for various species.

Another paper relates the results of behavioral studies on feeding in the puffer and their correlation with the electrical responses of the taste nerve. Those results can then be compared with two subsequent reviews of chemical stimulation of feeding behavior of fishes and of identification of gustatory feeding stimulants. Another chapter reviews baits in various fisheries, with emphasis on North Atlantic cod. Final chapters review chemoreception in salmonid homing and in fish communication, the adaptive significance of the alarm substance-fright reaction, and chemoreception and aquatic pollutants. Overall, the contributions are well written and the volume constitutes a good basic reference to the field; each chapter includes extensive references into the early 1980's. Hardbound, the 433-page volume is available from the publisher for US$91.50 or Dfl. 215.00 (and in the U.S. and Canada from Elsevier Science Publishers, Inc., P.O. Box 1663, Grand Central Station, New York, NY 10163.

Patterns and Processes Along the Rocky Shores

Publication of **"The Ecology of Rocky Coasts,"** edited by P. G. Moore and R. Seed, has been announced by the Columbia University Press, 562 West 113th Street, New York, NY 10025. The volume is dedicated to J. R. Lewis, a pioneer of British studies on the topic. Altogether there are 24 contributions which, with Lewis' own 1964 book "Ecology of Rocky Shores," form an impressive reference for students and researchers.

The volume is a compilation of three types of papers: Major "background" reviews, critical reviews of aspects of zonation or littoral ecology, and original research papers on the biology of certain species which contribute significantly to the overall community structure of rocky shores. And they are grouped into, first, descriptive surveys and zonation patterns, dynamics of key species, local heterogeneity, and the problems this poses for monitoring and surveillance programs. Thus, the diversity of the papers provides a good review of temperate rocky coastline ecology.

Included are reviews of the littoral epifaunal communities of algal fronds, meiofauna of seaweeds, and the amphipod fauna of kelp holdfasts. Another chapter provides a critical review on the influence of physical factors in controlling the grazing, competition, and distribution of rocky shore gastropods (in New South Wales), while yet another describes variation in shell shape of the dogwhelks.

Some of the more specialized contributions deal with biology of barnacles, gastropods, certain other very small littorinids, etc. Other general reviews deal with major features of rocky shore zonation, each stressing one particular dominant, and the role of mussels in the littoral zone. Additional contributions examine predation in rocky shore communities, reproductive strategies of North-temperate rocky shore invertebrates, detection of long-term trends in rocky sublittoral communities, community ecology of vertical rock walls in the Gulf of Maine, zonation of seaweeds on rocky shores, the organization of algal epifaunas, phytal meiofaunal ecology, and variation and persistence of rocky shore populations.

Other contributions develop themes on predation and optimal foraging theory and life history strategies for various species on rocky coasts. Overall, the chapters present an authoritative description of current knowledge and research on rocky shore ecology. The 467-page hardbound volume also has an excellent and lengthy list of references, and is available from the publisher for $45.00.

Australian Prawn Seminar Proceedings Are Published

The proceedings of the **"Second Australian National Prawn Seminar,"** edited by P. C. Rothlisberg, B. J. Hill, and D. J. Staples, has been published by NPS2, P.O. Box 120, Cleveland, Queensland, Australia 4163. The first seminar was held in 1973, the second in October 1984 with 51 papers and 9 posters presented. Topics covered include life histories, ecology, fisheries biology, aquaculture, commercial fisheries, population dynamics, and management aspects, and 34 of the presentations were included in the publication. Additional information on the 368-page paperbound volume is available from the publisher (price not listed).

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

Citations should be double-spaced and listed alphabetically by the senior author's surname and initials. Co-authors should be listed by initials and surname. Where two or more citations have the same author(s), list them chronologically; where both author and year match on two or more, use lowercase alphabet to distinguish them (1969a, 1969b, 1969c, etc.).

Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

Finally

First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

The senior author will receive 50 reprints (no cover) of his paper free of charge and 50 free copies are supplied to his organization. Cost estimates for additional reprints can be supplied upon request.

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